PB81-203028

# The IJC Menomonee River Watershed Study
# Land Use, Population and Physical Characteristics. Volume 2

Wisconsin Univ.-Madison

Prepared for

Environmental Protection Agency
Chicago, IL

Dec 79

U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

Great Lakes National
National Program Office
536 South Clark Street
Chicago, Illinois 60605

EPA-905/4-79-029-B

PB81-203028

Volume 2

# The IJC Menomonee River Watershed Study

## Land Use, Population And Physical Characteristics Of The Menomonee River Watershed

Menomonee River ★

PRODUCT OF:
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

# FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques, and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

The Great Lakes National Program Office (GLNPO) of the U.S. EPA, was established in Region V, Chicago to provide a specific focus on the water quality concerns of the Great Lakes. GLNPO also provides funding and personnel support to the International Joint Commission activities under the U.S.- Canada Great Lakes Water Quality Agreement.

Several land use water quality studies have been funded to support the pollution from Land Use Activities Reference Group (PLUARG) under the Agreement to address specific objectives related to land use pollution to the Great Lakes. This report describes some of the work supported by this Office to carry out PLUARG study objectives.

We hope that the information and data contained herein will help planners and managers of pollution control agencies make better decisions for carrying forward their pollution control responsibilities.

Madonna F. McGrath
Director
Great Lakes National Program Office

## TECHNICAL REPORT DATA

*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
| 1. REPORT NO.<br>EPA-905/4-79-029-B | 2. | 3. RECIPIENT'S ACCESSION NO.<br>PB81 203028 |
| 4. TITLE AND SUBTITLE<br>Land Use, Population and Physical Characteristics of the Menomonee River Watershed - Volume 2 | | 5. REPORT DATE<br>December 1979 |
| | | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) G. V. Simsiman<br>S.G. Walesh, F. Scarpace, B. Quirk, R. Meridith,<br>R. Frantoni, J. Goodrich-Mahoney, R. Bannerman | | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Wisconsin Department of Natural Resources<br>P.O. Box 450<br>Madison, Wisconsin 53701 | | 10. PROGRAM ELEMENT NO.<br>A42B2A |
| | | 11. CONTRACT/GRANT NO.<br>R005142 |
| 12. SPONSORING AGENCY NAME AND ADDRESS<br>U.S. Environmental Protection Agency<br>Great Lakes National Program Office<br>536 South Clark Street, Room 932<br>Chicago, Illinois 60605 | | 13. TYPE OF REPORT AND PERIOD COVERED<br>Final Report 1974-1978 |
| | | 14. SPONSORING AGENCY CODE<br>USEPA-GLNP |

15. SUPPLEMENTARY NOTES

University of Wisconsin System Water Resources Center and the Southeastern Wisconsin Regional Planning Commission

16. ABSTRACT

The Menomonee River Watershed is described in order to establish a factual base upon which to draw conclusions concerning the interactions of the ecosystem and the impact of water quality. The description includes natural and cultural features such as population, land use, climate, physiography and geology, soils and water storage areas. Also included in the description are the characteristics and management practices existing in the drainage areas of the mainstream and predominantly single land use monitoring sites.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Land data<br>Water quality<br>Water pollution<br>Nonpoint source<br>Remote sensing<br>Hydrological model | | |

| | | |
|---|---|---|
| 18. DISTRIBUTION STATEMENT<br>Document is available to the public through the National Technical Information Service (NTIS), Springfield, VA 22161 | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES<br>124 |
| | 20. SECURITY CLASS *(This page)* | 22. PRICE |

EPA Form 2220-1 (9-73)

☆ U. S. Government Printing Office: 1981 750-801

EPA-905/4-79-029-B
December 1979

# LAND USE, POPULATION AND PHYSICAL CHARACTERISTICS OF THE MENOMONEE RIVER WATERSHED

## Volume II

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This Study, funded by a Great Lakes Program grant from the U.S EPA, was conducted in cooperation with the Wisconsin Department of Natural Resources, the University of Wisconsin System Water Resources Center and the Southeastern Wisconsin Regional Planning Commission.

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# DISCLAIMER

This report has been reviewed by the Great Lakes National Program Office of the U.S. Environmental Protection Agency, Region V Chicago, and approved for publication. Mention of trade names of commercial products does not constitute endorsement or recommendation for use.

# PREFACE

This volume constitutes a detailed description of the Menomonee River Watershed and is designed in such a fashion as to allow, I. a description of the Land Data Management System developed by the Southeastern Wisconsin Regional Planning Commission; II. an evaluation of the ability to use remote sensing for making a sufficiently sensitive land use inventory to be applicable to urban settings; descriptions of land use, soils and landscape features of III, the entire Watershed, and IV, the 48 subwatersheds of area 132 to 11,610 ha.

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*Detailed contents are presented in the beginning of each part.

# PART I

# LAND DATA MANAGEMENT SYSTEM

by

S. G. WALESH

# ABSTRACT

The Land Data Management System was developed by the SEWRPC in order to provide an inventory of land use characteristics to be used in investigating the impact of land uses on water quality. The Land DMS is a digital computer-based system designed to store, retrieve, analyze and display, in tabular or graphic form, land data for the Menomonee River Watershed.

The Land DMS is a practical tool that can optimize the use of available data thereby enhancing the quality of the decision-making process in land and water resource planning. Practical applications of the land data management system prepared for or used by the IJC-Menomonee River Pilot Watershed Study participants include both graphic and tabular display of data.

Some of the more important advantages of the Land Data Management System are: a. handling data at the available level of detail; b. minimal manual handling of data; c. ease of update and correction; d. quick response; e. overlay capability; and f. availability of a variety of tabular and graphic outputs.

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# ACKNOWLEDGMENT

The study covered in this article was a part of the efforts of the Pollution from Land Use Activities Reference Group, an organization of the International Joint Commission, established under the Canada-United States Great Lakes Water Quality Agreement of 1972. Funding was provided by the U.S. Environmental Protection Agency through the Wisconsin Department of Natural Resources.

# I-1. INTRODUCTION

The Land Data Management System (Land DMS) is a digital computer-based system designed to store, retrieve, analyze and display in tabular or graphic form land data for the Menomonee River Watershed. The term "land data" as used in the Land DMS is a comprehensive concept that denotes all those types of natural resource and man-made features data that have an areal characteristic. Examples include land use, land cover, soil type, civil division and zoning information. The System was developed by the Southeastern Wisconsin Regional Planning Commission in order to provide an inventory of land use characteristics to be used in investigating the impact of various land uses on water quality.

## I-2. SUMMARY AND CONCLUSIONS

The Land Data Management System was developed by the SEWRPC in order to provide an inventory of land use characteristics to be used in investigating the impact of land uses on water quality. The Land DMS is a digital computer-based system designed to store, retrieve, analyze and display, in tabular or graphic form, land data for the Menomonee River Watershed.

The Land DMS is a practical tool that can optimize the use of available data thereby enhancing the quality of the decision-making process in land and water resource planning. Practical applications of the land data management system prepared for or used by the IJC-Menomonee River Pilot Watershed Study participants include both graphic and tabular display of data.

Some of the more important advantages of the Land Data Management System are:

a. Handling data at the available level of detail;

b. Minimal manual handling of data;

c. Ease of update and correction;

d. Quick response;

e. Overlay capability; and

f. Availability of a variety of tabular and graphic outputs.

The principal disadvantage of the system is the initial high cost and cost of maintenance. Thus, such systems are likely to be economically feasible and otherwise practical in the context of a long range, well-established comprehensive regional or metropolitan planning program.

## I-3. METHODS AND PROCEDURES

### Data Storage Unit

The basic areal unit for storing, retrieving, analyzing and displaying land data is "the cell." At the time the system was designed, in 1974, the "cell mode" approach to data base organization was selected over the "area boundary" approach because the cell mode was judged to be more technically and economically feasible with respect to the effort required to code areal data from primary sources. Also, less computer programming and computer capacity were required to store, retrieve, analyze, and display land data, including the use of overlay techniques.

In applying the Land DMS, the geographic unit of interest, such as the watershed or civil division is subdivided into cells by partitioning United States Public Land Survey quarter sections as shown in Fig. I-1. Specifically, each of the four sides of each quarter section is divided into eight equal segments and the division points on opposite sides of the quarter section are connected, resulting in 64 cells per quarter section, each having a nominal area of 1.0 hectare (2.5 acres).

The use of cells that are partitions of U.S. Public Land Survey quarter sections has one principal advantage. It facilitates geo-referencing of each cell since horizontal survey control, in the form of state plane coordinates, has been established by SEWRPC and by local units of government. Survey control is transferrable directly by computation to the centers and corners of each cell for approximately one-third of the U.S. Public Land Survey quarter section corners in the 6,965 $km^2$ (2,689 $mi^2$) planning region using field survey methods. The second reason for forming cells by subdividing each U.S. Public Land Survey section was to permit aggregating the resulting data to the quarter section level so as to be directly comparable to SEWRPC 1963, 1967 and 1970 land use data and other data that were coded and filed on a quarter-section basis.

Each cell is identified by township, range, section, quarter section, and cell number. Cells are numbered 1 through 64 within each quarter section, beginning in the upper right hand corner and proceeding to the left, dropping down one row and proceeding from left to right, dropping one row and proceeding from right to left and continuing in this serpentine fashion to cell number 64. It is important to note that cell-based systems could be developed within the framework of other rectilinear reference systems such as latitude and longitude or the Universal Transverse Mercator System.

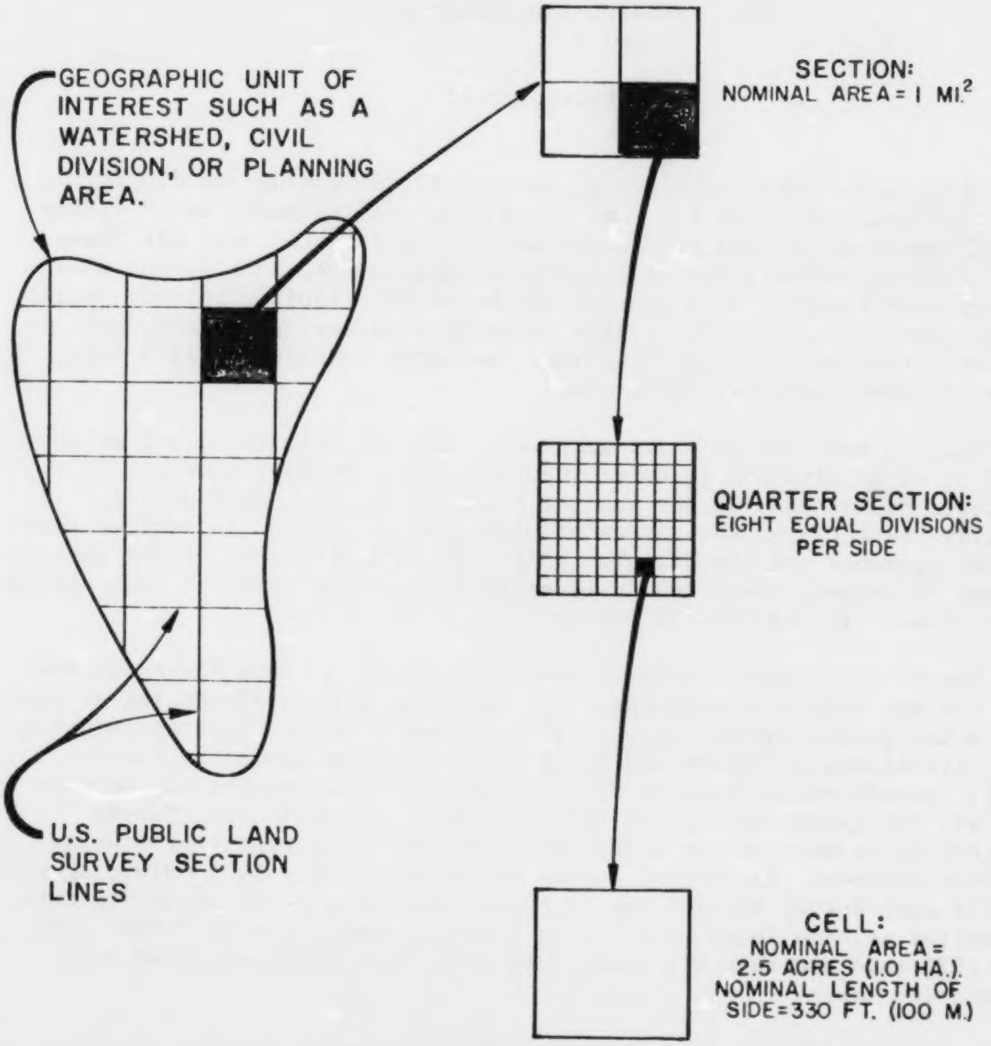

GEOGRAPHIC UNIT OF INTEREST SUCH AS A WATERSHED, CIVIL DIVISION, OR PLANNING AREA.
SECTION: NOMINAL AREA = 1 MI.²
QUARTER SECTION: EIGHT EQUAL DIVISIONS PER SIDE
U.S. PUBLIC LAND SURVEY SECTION LINES
CELL: NOMINAL AREA = 2.5 ACRES (1.0 HA.). NOMINAL LENGTH OF SIDE=330 FT. (100 M.)

Fig. I-1. "The Cell," the basic areal unit of the Land DMS.

## Geo-Referencing

An accurate geo-referencing arrangement is required to permit computation of the area of each cell or of groups of cells and to facilitate display, in computer plotted map form, of selected land data. The best available sources of information are used to first determine the state plane coordinates of the U.S. Public Land Survey corners of each quarter section contained wholly or partly in the geographic unit of interest. Plane geometry is then used via software within the Land DMS to calculate the state plane coordinates of each corner and of the center of each cell. The Land DMS also can readily convert--again using software within the system--the cell corner coordinates to other geo-referencing systems such as latitude and longitude and the Universal Transverse Mercator System.

## The Supporting Computer System

The combination of hardware and software needed to support the Land DMS can be broken into four phases as shown in Fig. I-2: a. input; b. data manipulation; c. data base; and d. output. Under the input phase, data are entered into the Land DMS on either magnetic diskettes or punched cards. The second, or data manipulation phase, computer programs that perform contingency checks on the incoming data, provide for maintenance and updating of the data, analyze the data, and prepare it for transfer back to the user. The analysis ability of this phase facilitates the identification of cells having specified combinations of land data types. The data base phase, may be viewed as a large "file cabinet" with many "drawers," as shown in Fig. I-3. Each drawer corresponds to each of the types of areal data on file in the Land DMS. The fourth, or output phase, provides for transfer of land data to the user in a variety of formats. For example, land data can be outputted on a cell basis or aggregated by civil division or some other geographical area of interest. Output can be obtained on several media including magnetic tape, punch cards, line printer and plotter.

Computer system hardware currently used to operate the Land DMS consists of an IBM Model 370/135 computer, IBM Model 3410 tape drives and Model 3340 desk packs, an IBM Model 1403 printer and a Calcomp Model 905 drum plotter.

## Land Data Contained in the System

To date the system has been applied to the 352 km$^2$ (136 mi$^2$) urbanizing Menomonee River Watershed. Table I-1 sets forth the current status of land data contained in the Land DMS for the Menomonee River Watershed including the medium from which each type of land data was extracted, and the type of cell coding. Table I-1 is intended to show the range of data types that can be accommodated, the variety of data sources and the types of coding that can be used.

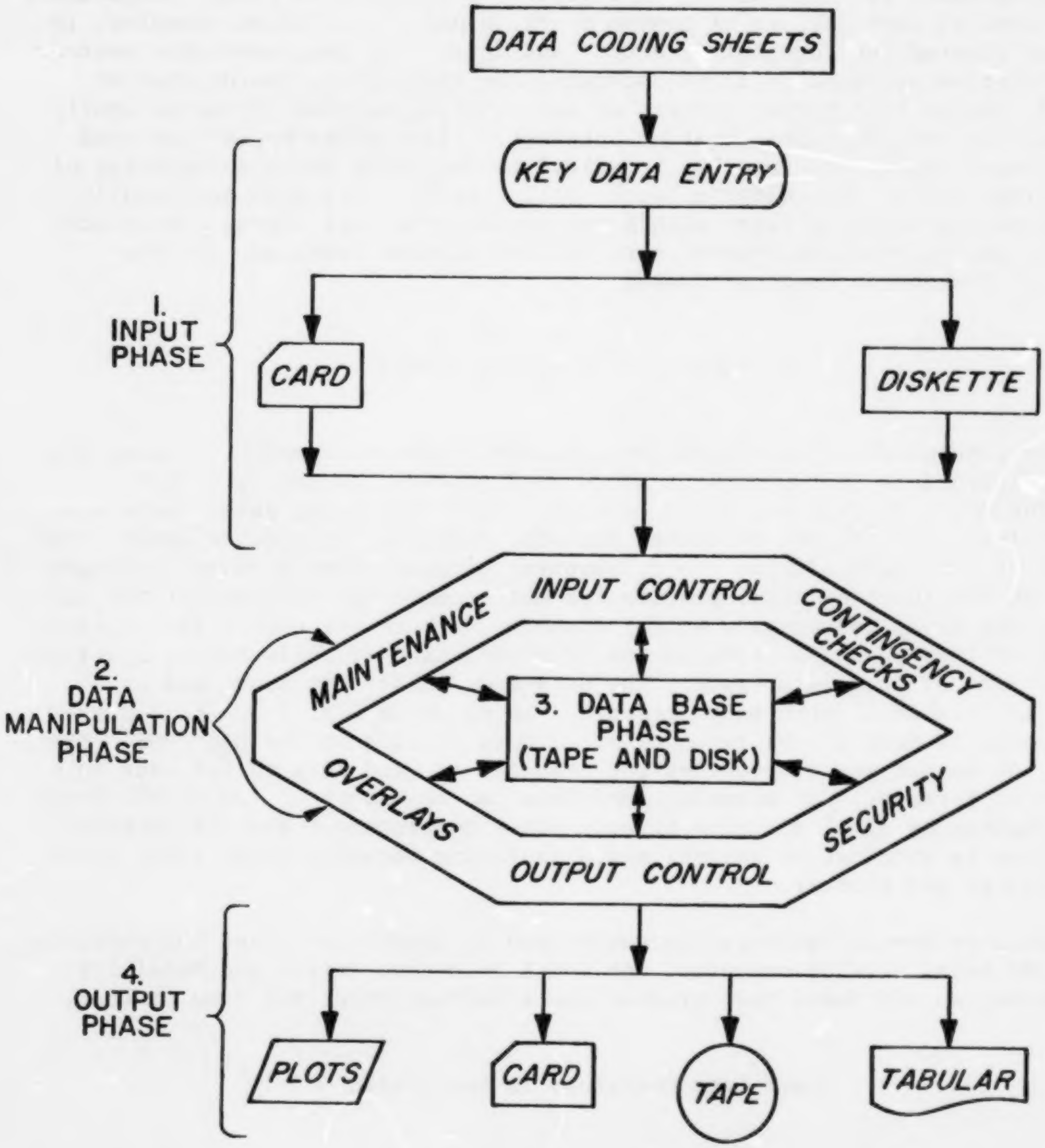
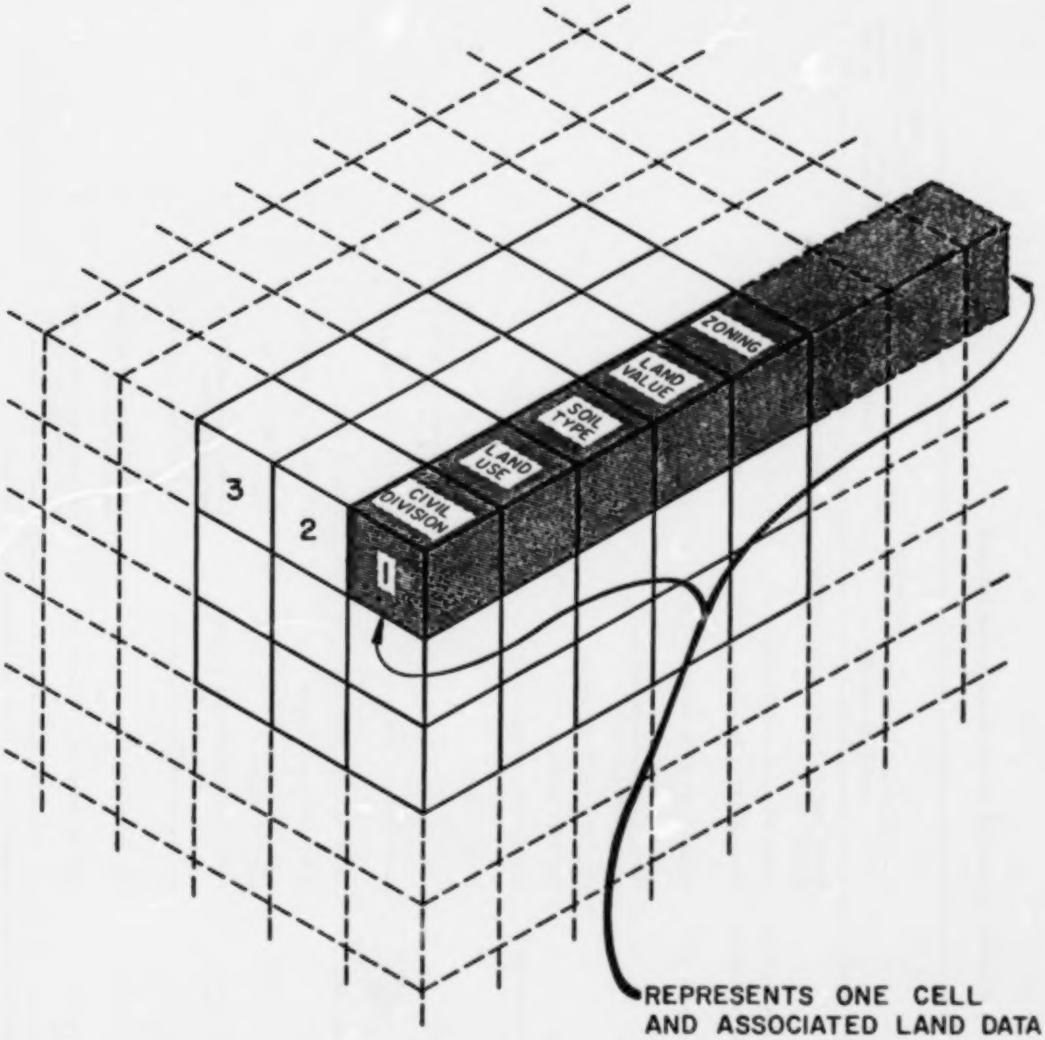

DATA CODING SHEETS
KEY DATA ENTRY
1. INPUT PHASE
CARD
DISKETTE
INPUT CONTROL
MAINTENANCE
CONTINGENCY CHECKS
2. DATA MANIPULATION PHASE
3. DATA BASE PHASE (TAPE AND DISK)
OVERLAYS
SECURITY
OUTPUT CONTROL
4. OUTPUT PHASE
PLOTS
CARD
TAPE
TABULAR

**Fig. I-2. Computer hardware and software supporting Land DMS.**


ZONING
LAND VALUE
SOIL TYPE
LAND USE
CIVIL DIVISION
3
2
1
REPRESENTS ONE CELL AND ASSOCIATED LAND DATA

NOTE: ACCESS TO DATA BASE IS BY CELL OR BY LAND DATA TYPE.

Fig. I-3. Schematic representation of data base phase of Land DMS.

Table I-1. Status of data in the land DMS for the Menomonee River watershed

| Data type | Data source | | Type of coding | | |
|---|---|---|---|---|---|
| | Agency or project | Medium | Dominant characteristic | Percent of cell | Other |
| Civil division | SEWRPC land use-transportation planning program | 1:24,000 map | X | | |
| Sub-basins and subwatersheds | SEWRPC watershed planning program | 1:24,000 map | X | | |
| Wildlife habitat (with value ratings) | Wisconsin DNR Field Survey | 1:4,800 aerial photographs | X | | |
| Woodland-wetland (with value ratings) | Wisconsin DNR Field Survey | 1:4,800 aerial photoraphs | X | | |
| Park and outdoor recreation sites | SEWRPC park, recreation and open space planning program | 1:24,000 map | X | | |
| Floodlands | USGS flood hazard delineation | 1:24,000 map | X | | |
| Perennial streams | USGS quadrangle maps | 1:24,000 map | | | X* |
| Conservancy, floodland and related zoning | Community Zoning regulations | Miscellaneous maps | X | | |
| Soils** | SCS Soil Survey | 1:24,000 and 1:12,000 maps | | X | |
| Ground elevation | --- | Best available topographic maps | | | X*** |
| Land use-1970 | SEWRPC land use inventory | 1:4,800 aerial photograph overlays | | X | |
| Riverine area land value | SEWRPC watershed planning program | 1:24,000 maps | X | | |
| Land use-1975 | SEWRPC land use inventory | 1:4,800 aerial photographs | | X | |
| Residential density codes | SEWRPC land use-transportation planning program | SEWRPC Regional Density File | X | | |
| Monitoring stations and area tributary to the (12) | SEWRPC watershed planning program | Sub-basin maps and 1:4,800 aerial photographs | X | | |
| Water ResourcesCenter-special study sites (7) | Water ResourcesCenter delineation | 1:4,800 aerial photographs | X | | |
| DNR subwatersheds (48) | DNR delineation | Sub-basin maps and 1:4,800 aerial photographs | X | | |
| Water ResourcesCenter subwatersheds (51) | Water ResourcesCenter delineation | Sub-basin maps and 1:4,800 aerial photographs | X | | |

*A cell is coded as "perennial stream" if such a stream crosses any part of the cell.
**Soil type, degree of erosion and ground slope.
***The ground elevation of a cell is taken as the elevation at its center.

Land data are extracted from the source material and coded on either a "dominant characteristic" or "percent of cell" basis. Coding on the dominant characteristic basis--which is used when the source data are either unavailable at a high degree of resolution or a high degree of resolution is not needed--consists of determining the dominant characteristic in a given cell for a particular data type. Coding on a percent of cell basis is used when the data are available at high resolution compared to the cell size and when anticipated uses require high resolution. For example, it may be desirable to code land use on a "percent-of-cell" basis with three types of land use present in a particular cell. Land use is coded by indicating the amount of cell area occupied by each of the three land uses with the relative amount being determined by laying a transparent mylar overlay with a uniform dot pattern over the cell and recording the number of dots contained within each of the three land uses. Table I-2 is a typical land use coding sheet used for coding on a percent of cell basis. Software in the Land DMS uses the dot counts to determine the absolute area of each of the three land uses present within the cell, by using as "control totals" the known areas of the cell itself based on second order precision land survey data developed in accordance with the land survey and monumentation methods of the SEWRPC. Coding land use under the dominant characteristics basis would consist of identifying the land use occupying the largest portion of the cell and assigning it to the entire cell.

## Application of the Land DMS

On a practical basis, the Land DMS is applied to a geographic area of interest such as a watershed or civil division by partitioning the area of interest into cells, coding the land data types of interest to the cells, inputting them to the system, and retrieving, analyzing and displaying the data as needed. The number of applications of such systems are unlimited because of the wide variety of combinations of data types that can be used and because of the variety of output formats available. Several diverse applications are presented to illustrate the versatility and practicality of the system in land and water resources planning. Each of the applications is drawn from uses in the Menomonee River Pilot Watershed Study.

### Graphic or tabular display of data

The simplest use of the Land DMS is to display, in graphic or tabular form, one or more land data types for a given geographic area. Tabular output is shown in Table I-3 in the form of quantified land use and soil data for an in-watershed portion of a given U.S. Public Land Survey section. Graphic output from the Land DMS is shown in Fig. I-4 in the form of mapped land use data by cell for the same section. Maps can be produced by the system at essentially any scale, and maps and tables can be constructed in any desired format. A variety of special graphic displays can be created, for example, isometric representations of surface topographic features.

Table I-2. Typical land use coding sheet

| TOWNSHIP | RANGE | SECTION | QUARTER SECTION | CELL IDENTIFICATION NUMBER | LAND USE CODE[a] | NUMBER OF DOTS[b] |
|---|---|---|---|---|---|---|
| 7 | 21 | 7 | 1 | 1 | 55 | 8 |
| | | | | 1 | 75 | 20 |
| | | | | 2 | 75 | 28 |
| | | | | 3 | 58 | 6 |
| | | | | 3 | 75 | 22 |
| | | | | 4 | 54 | 5 |
| | | | | 4 | 75 | 23 |
| | | | | 5 | 75 | 28 |
| | | | | 6 | 90 | 5 |
| | | | | 6 | 55 | 2 |
| | | | | 6 | 75 | 21 |
| | | | | 58 | 51 | 3 |
| | | | | 58 | 75 | 25 |
| | | | | 59 | 75 | 28 |
| | | | | 60 | 75 | 28 |
| | | | | 61 | 75 | 28 |
| | | | | 62 | 75 | 28 |
| | | | | 63 | 75 | 28 |
| | | | | 64 | 55 | 8 |
| | | | | 64 | 75 | 20 |

[a] SEWRPC LAND USE CODE

[b] USING A TRANSPARENT DOT COUNTER

Table I-3. Example of tabular output from Land DMS for Township 7 North, Range 20 East, Section 28

```
                    LAND USE DATA BY LAND USE TYPE

                                   AREA IN SECTION     PERCENT OF
 SECTION       LAND USE CODE           (ACRES)           TOTAL
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 0720-28            00                  65.24            16.46
                    05                  11.55             2.91
                    10                  13.02             3.28
                    20                    .28              .07
                    54                  10.77             2.72
                    55                   8.61             2.17
                    58                   8.24             2.08
                    59                  15.13             3.82
                    60                  15.17             3.83
                    72                    .37              .39
                    80                  83.82            21.14
                    82                   1.19              .30
                    91                  12.17             3.07
                    92                  22.98             5.80
                    94                 127.92            32.27
                                       ------
TOTAL                                  396.44           100.01
```

```
                  SOIL DATA BY CELL

                         CELL       SOIL
         SECTION          NO.       CODE      ACRES
- - - - - - - - - - - - - - - - - - - - - - - - - - - -
       0720-28-1          01        0073        .73
                                    0357       1.72
                          02        0073        .73
                                    0076        .99
                                    0357        .48
                                    0450        .25
                          03        0076        .99
                                    0450       1.47
=========================//============================
                          60        0212        .25
                                    0364       2.27
                          61        0299       1.52
                                    0364       1.01
                          62        0299       2.27
                                    0363        .25
                          63        0076        .25
                                    0363       2.25
                          64        0076        .25
                                    0363       2.25
       0720-28-2          01        0450       2.55
                          02        0450       2.55
                          13        0450       2.55
                          14        0450       2.55
                          15        0450       2.55
                          16        0450       2.55
                          17        0450       2.55
                          18        0450       2.55
                          19        0450       2.55
                          20        0450       2.55
                          21        0450       2.55
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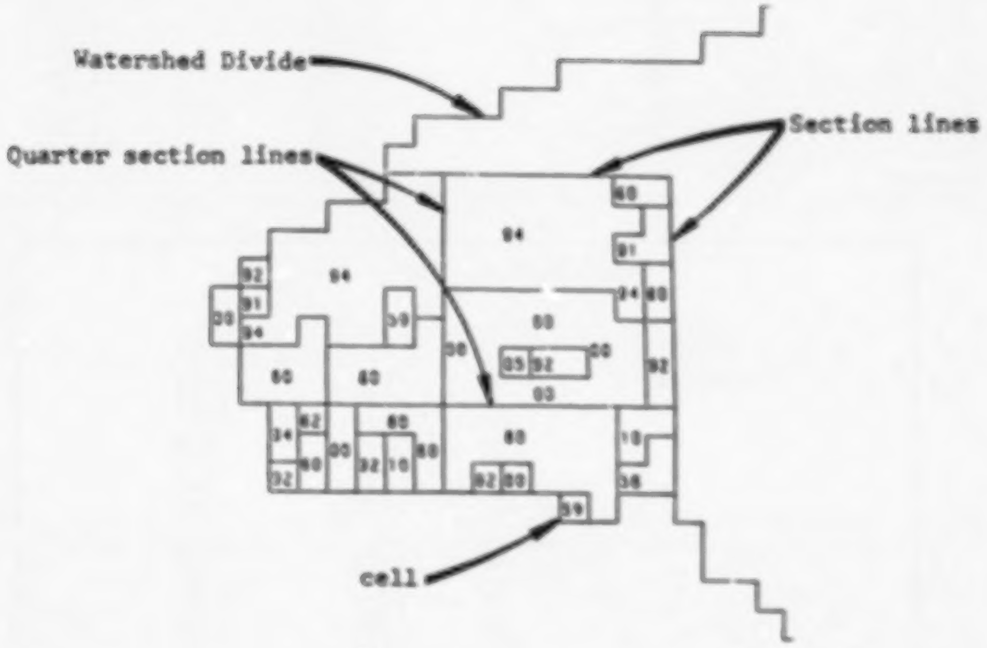
Watershed Divide
Section lines
Quarter section lines
cell

Fig. I-4. Example of graphic output from Land DMS for Township 7 North, Range 20 East, Section 28. The scale is 1:24,000; numbers indicate code of dominant land use.

## Overlay capabilities

The Land DMS is capable of retrieving, analyzing and displaying information for areas having particular combinations of land characteristics. As shown in Table I-4, output using this technique combines land use data and slope data by subbasin. This example quantifies a total of six different land use types together with their associated slopes.

A portion of the watershed having a particular combination of soil data and land use data is shown in Fig. I-5. This map illustrates residential land uses and denotes within each cell a code relating to soil type categorized by soil permeability.

Typical applications using the Land DMS by participants of the Menomonee River Pilot Watershed Study are shown in Table I-5.

## Advantages and Disadvantages of the System

The System and other similar systems have positive and negative features that should be considered by potential users. Some of the more important advantages of land data management systems are:

a. The data are stored and analyzed at the level of detail, i.e., the resolution, at which they are available. This contrasts with manual handling of data where a tendency exists to aggregate data to larger areal units in order to minimize the amount of effort involved.

b. Minimal manual handling of basic data is required, i.e., after the data have been entered into the system, analyses are performed by computer in response to programmed instruction, thereby minimizing errors in data handling.

c. The data can be updated and corrected by entering new or refined information into the system.

d. Because of the relatively quick turnaround time quantitative information can be supplied to decision makers in a matter of hours.

e. The System processes analytical capability, primarily in its ability to overlay many land data types.

f. These systems provide tabular and graphic materials for decision making and report preparations.

The primary disadvantage of these systems is the cost of performing the initial data coding, loading into the system and maintaining and updating the data.

In light of these cost considerations, it appears that digital

**Table I-4. Example of tabular output using overlay capabilities from Land DMS**

```
 LAND USE a           SLOPE b    ACRES          PERCENT
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
     00                01         1.91            3.35
                       02         6.24           10.95
                       03        25.11           44.07
                       04         7.55           13.25
                       05        15.79           27.71
                       07          .37             .65
                                 ------          ------
    TOTAL                        56.97           99.98

     05                03         1.65           60.44
                       05         1.08           39.56
                                 ------          ------
    TOTAL                         2.73          100.00

     54                01          .64            7.66
                       02         1.38           16.51
                       03         4.22           50.48
                       04          .37            4.43
                       05         1.74           20.81
                                 ------          ------
    TOTAL                         8.35           99.89

     55                03          .28           25.45
                       04          .55           50.00
                       05          .28           25.45
                                 ------          ------
    TOTAL                         1.11          100.90

     80                02        15.20           12.50
                       03        68.39           56.24
                       04        16.78           13.80
                       05         6.40            5.26
                       06         7.60            6.25
                       07         7.23            5.95
                                 ------          ------
    TOTAL                       121.60          100.00

     94                02         5.05           30.13
                       03        11.71           69.87
                                 ------          ------
    TOTAL                        16.76          100.00

 BASIN TOTAL                    207.52
```

[a] 1970 Land use classification system.

[b] Percent slope or fall/100 ft on which mapped soil occurs. Land use data and slope data are by sub-basin.

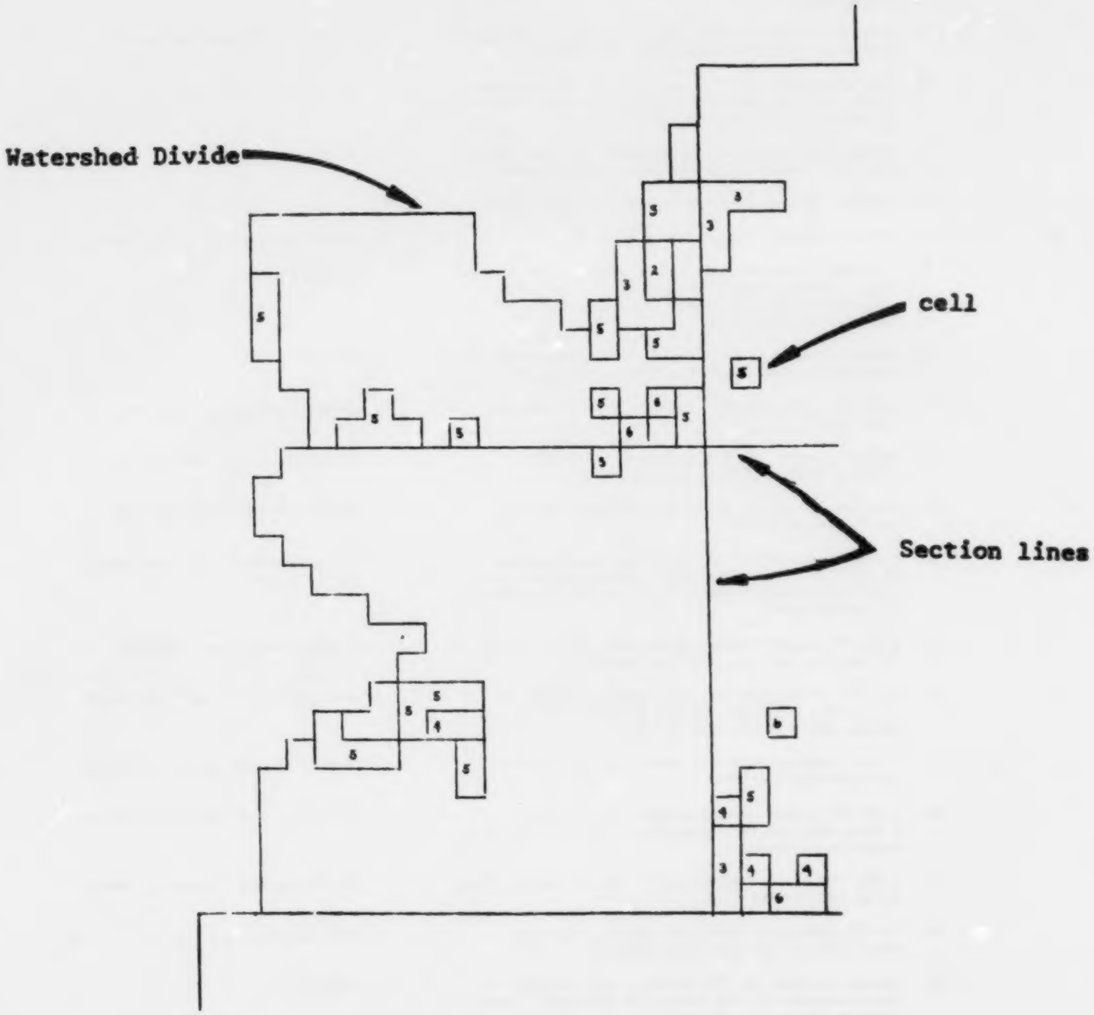
Watershed Divide
3
5
3
2
3
cell
5
5
5
5
5
6
5
5
5
6
5
Section lines
5
5
4
6
5
5
5
4
3
4
4
6

Fig. I-5. Example of graphic output using overlay capabilities from Land DMS for a combination of land use and soil data. The scale is 1:24,000; only cells with a dominant land use of residential type are displayed. Numbers indicate code relating to soil type categorized by soil permeability.

Table I-5. Typical applications of the land data management system developed under the IJC-Menomonee River Pilot Watershed Study: May 1976 to February 1978

| | Application | Prepared for or used by |
|---|---|---|
| 1. | 1:4,800 scale computer maps showing boundaries of three monitoring stations to be used for overlaying on aerial photographs. | UW-Madison-Water Resources Center |
| 2. | 1:48,000 scale and 1:24,000 scale map of aggregated land uses in the Menomonee River Watershed. | UW-Madison-Geology Department |
| 3. | Tabular summary of 1970 land use for all Menomonee River watershed sub-basins; 1:24,000 scale computer map of dominant 1970 land use per cell. | Marquette University |
| 4. | Tabular summary of each combination of slope and 1970 land use existing in sub-basins of the Watershed. | Marquette University |
| 5. | Tabular summary of percent impervious area by sub-basin. | Marquette University |
| 6. | Tabular summary of land use by section. | UW-Madison-Water Resources Center |
| 7. | 1:24,000 scale computer map of dominant land use per cell. Tabular summary of land use by sub-basin, subwatershed and watershed and by area tributary to 12 monitoring stations. | WDNR-Madison |
| 8. | Tabular summary of soil types with a greater than 5% distribution and slopes for each sub-basin. | WDNR-Milwaukee |
| 9. | 1:24,000 and 1:48,000 computer maps of dominant soil types. | UW-Madison-Geology Department |
| 10. | Tabular summary of 1975 land uses for the 51 subwatersheds designated for the study. | UW-Madison-Water Resources Center |
| 11. | Computer soils maps based upon permeability and depth to water table. | UW-Madison-Geology Department |
| 12. | A tabular summary of 1975 land use data together with soils, slope and erosion information for the seven predominantly single land use sites monitored in the Watershed. | UW-Madison-Water Resources Center |
| 13. | 1:48,000 scale computer maps combining soils with "C" horizon data and 1975 land use data. | UW-Madison-Geology Department |
| 14. | 1:4,800 scale maps of soils, slopes, degree of erosion and 1975 land use for each of the seven predominantly single land use sites. | UW-Madison-Water Resource Center |
| 15. | Tabular summary of soils, slope and 1975 land data by monitoring stations. | UW-Madison-Water Resources Center |
| 16. | 1:24,000 scale computer maps of soils, slope, erosion data and 1975 generalized land use for each monitoring station. | UW-Madison-Water Resources Center |
| 17. | 1:126,720 scale computer map of the 51 subwatersheds designated for the study. | UW-Madison-Water Resources Center |
| 18. | Tabular summary of 1975 land use and degree of imperviousness for each subwatershed. | WDNR-Madison |
| 19. | Tabular summary of 1975 land use and degree of imperviousness for the sub-basins tributary to the mainstem monitoring stations. | WDNR-Madison |
| 20. | Use of cell system to assign density code to residential lands to estimate imperviousness of an area. | SEWRPC |
| 21. | Tabular summary of soils, slope, imperviousness and 1975 land use data for 51 subwatersheds designated for the study. | UW-Madison-Water Resources Center |
| 22. | 1:126,720 scale computer map of the 51 subwatersheds designated for the study. | WDNR-Madison |
| 23. | Tabular summary of soil and slope data for each subwatershed. | WDNR-Madison |
| 24. | Tabular summary of combination of land use, soils and slope data for each subwatershed. | WDNR-Madison |
| 25. | Tabular summary of land use, soils and slope data for the sub-basins tributary to the mainstem monitoring stations. | WDNR-Madison |

computer-based data handling systems are likely to be economically feasible in land and water resource research and planning projects only where there is extensive use of the system over a long period.

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# PART II

# THE USE OF REMOTE SENSING TO DETERMINE LAND COVER IN THE MENOMONEE RIVER WATERSHED

by

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B. QUIRK
R. MERIDITH
R. FRATONI

# ABSTRACT

Land cover information for a hydrological model was provided by digital analysis of aerial photography. A fast method for obtaining land cover information in the Menomonee River Watershed was tested and found to be cost effective. Thematic representations as well as tabular information was produced. Accuracy of approximately 90% was determined for the digitally classified imagery when compared to ground truth.

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# II-1. INTRODUCTION

Following passage of the Federal Water Pollution Control Act (P.L. 92-500) in 1972, state and federal agencies intensified their interest in point and non-point sources of water pollution. Until recently emphasis has been on point sources because they are easier to detect, monitor and treat. Currently, greater research emphasis is being placed on non-point water pollution; two sources of particular concern are urban uses and construction sites.

Since one of the important input parameters to the overland flow model LANDRUN--which was being tested in the investigation--is land cover, remote sensing was investigated as a possible method of obtaining land cover information. The most widely used remote sensing technique is manual photo interpretation of large scale aerial imagery in conjunction with ground-based field work. Although sufficiently accurate for land cover interpretation in urban areas, this method has proven costly and time-consuming when implemented on areas larger than a few square miles (1).

A second method of obtaining land cover information is by computer analysis of LANDSAT tapes (2,3,4). Although this method is faster and less expensive, it has several drawbacks. One is the 1.1 acre (0.5 ha) resolution cell of the LANDSAT satellite. This requires the amount of impervious surface to be measured indirectly by assigning to each land cover category a predetermined amount of imperviousness. The total amount of impervious surface for each land cover category is calculated by multiplying the number of cells classified for each land cover by the percentage of imperviousness for the land cover category, times 1.1 acres. This technique seems to work well in rural areas, but is less accurate than other techniques in urban areas (5).

A second problem, particularly in Wisconsin, is acquiring cloudless LANDSAT imagery. The ideal season to obtain imagery for mapping land cover, especially impervious land cover, is in the early spring or late fall. Unfortunately this is when the number of cloudless days are at a minimum (6). This time restriction favors analysis of aerial photography instead of LANDSAT imagery for land cover interpretation because the LANDSAT satellites have a fixed schedule while aerial photography can be acquired on any cloud-free day. The goal of this investigation was to develop and test the technique of digital analysis of aerial photography for land cover mapping in urban areas.

# II-2. CONCLUSIONS

A cost-effective method of mapping current land cover in an urban area has been demonstrated. The technique involves the use of digitized aerial imagery (either color or color-infrared) that has been properly calibrated. The calibrated digital imagery is classified using a two-stage elliptical table-look-up algorithm which produces a tabular presentation of different land cover classes as well as a thematic representation. The accuracy of the classification was checked by ground calibration and photo interpretation of reconstituted images.

To effectively use hydrologic transport models such as LANDRUN, accurate, current information on land cover is needed. It is believed that remote sensing techniques may be the only practical method of ascertaining such information in a timely fashion. The digital analysis of aerial imagery seems to be superior to the analysis of LANDSAT tapes in an urban area because of the better resolution and versatility in choosing the date of imagery.

## II.3 MATERIALS, METHODS AND PROCEDURES

### Digitized Photography

Procedures for digitally analyzing aerial photography are essentially the same for color or color-infrared film, the significant difference being in the interpretation of the data derived from the densitometric analysis of the imagery. Since the analysis procedures are similar for all types of multi-emulsion imagery, only a detailed description for color films will be presented. Extensions to the analysis of color-infrared imagery will be indicated in the appropriate sections.

Incident energy from the earth's surface is recorded on a color image in the form of various amounts of colored dyes. The colored dyes used are yellow, magenta, and cyan. At each spatial location on the processed imagery there exists some concentration of yellow, magenta, and cyan dyes. In general, the concentrations of each of these dyes differ from each other as well as differing from the dye concentrations at adjacent parts of the imagery. It is the intent of densitometry on multi-emulsion imagery to infer the amounts of each dye at each spatial location of interest on the imagery. From this data the amount and (to some extent) the spectral distribution of the incident energy on the unexposed film can be inferred.

The structure of a typical color film is shown in Fig. II-1. From the point of view of the user, the three important layers are the ones that are sensitive to the blue, green and red light. Curves representing the sensitivities of these layers can be found in Fig. II-2. After the film has been exposed to visible light and processed, yellow, magenta and cyan dyes are formed in their respective layers. In a color reversal film (such as Kodak Aerochrome MS Film 2448) the amount of dye formed in each layer depends inversely on the amount of light sensitizing each layer. An object that appears blue in nature will, after processing, cause an image to contain a relatively small amount of yellow dye, and proportionately larger amounts of magenta and cyan dyes. Since magenta and cyan dyes absorb the green and red light, the image will appear blue in normal lighting conditions. To infer the amounts of the dyes present in the imagery, some type of measurement must be made on the developed transparency.

These measurements are made by placing the imagery on a scanning microdensitometer which converts the amounts of dye in each of the image layers to a density value.

Densitometry on multi-emulsion imagery has been described adequately elsewhere (7,8,9), thus only a short review of the salient points are presented here. Because of the colored dyes present in the imagery, any density

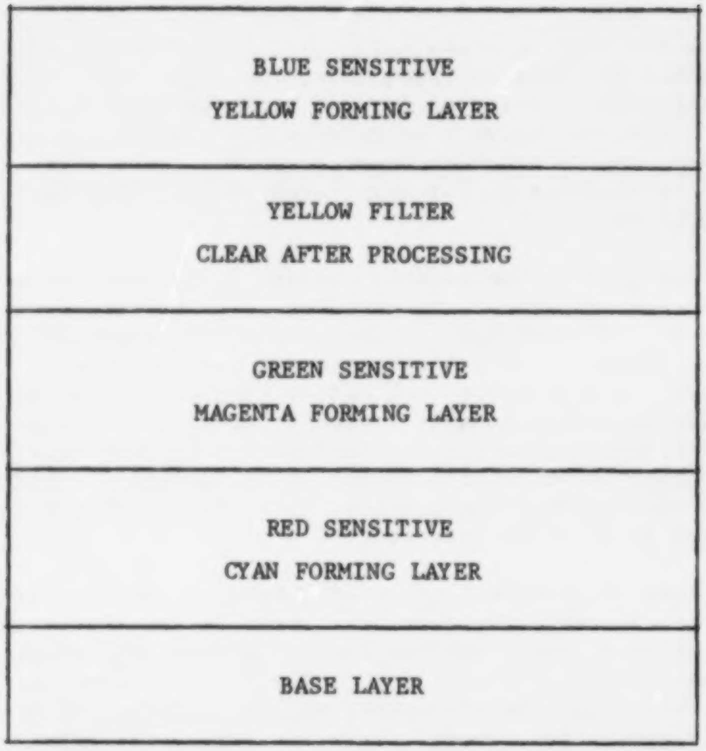
BLUE SENSITIVE
YELLOW FORMING LAYER
YELLOW FILTER
CLEAR AFTER PROCESSING
GREEN SENSITIVE
MAGENTA FORMING LAYER
RED SENSITIVE
CYAN FORMING LAYER
BASE LAYER

Fig. II-1. Kodak Aerochrome MS Film 2448, Estar Base.

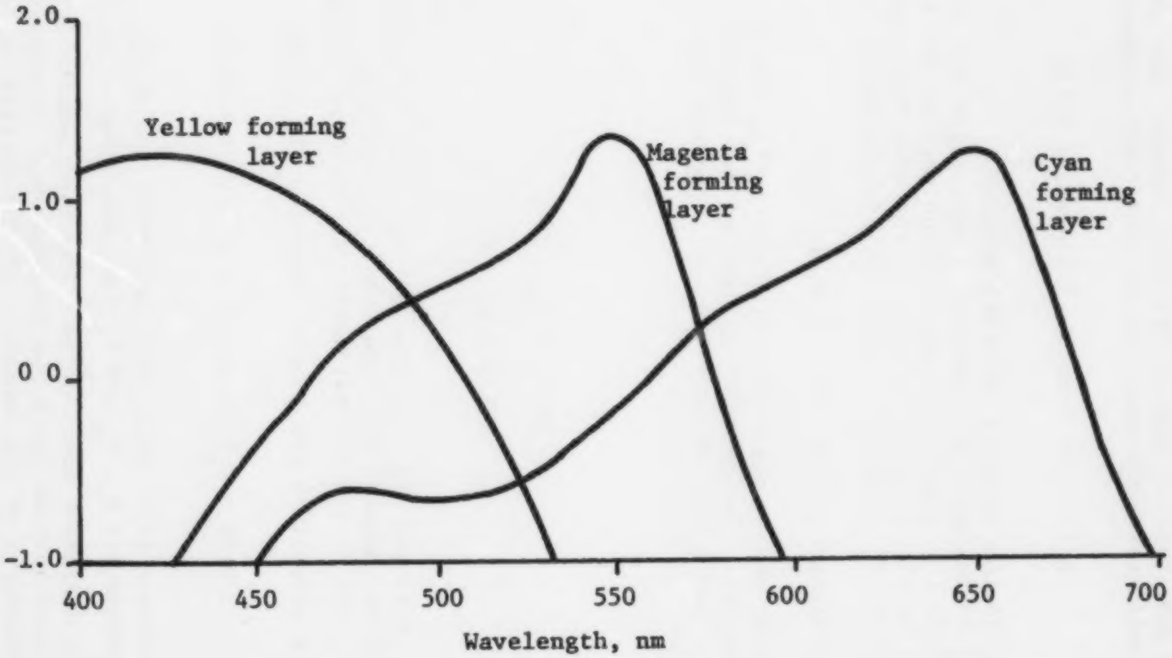

Fig. II-2. Spectral sensitivity curves for Kodak Aerochrome MS Film 2448, Estar Base.

measurement on multi-emulsion imagery is wavelength dependent. Spectral density is a measure of density at a particular wavelength. Any density measurement on multi-emulsion film is an integral density measurement. It is an integral density measurement because the measured density depends on the individual dye densities of each of the film layers. The integral spectral density for a multi-emulsion image can be expressed mathematically as:

$$D(\lambda) = DY(\lambda) + DM(\lambda) + DC(\lambda) + DB(\lambda) \qquad \text{Eq. (1)}$$

where:
$D(\lambda)$ is the integral spectral density
$DY(\lambda)$ is the spectral density of the yellow dye layer
$DM(\lambda)$ is the spectral density of the magenta dye layer
$DC(\lambda)$ is the spectral density of the cyan dye layer
$DB(\lambda)$ is the spectral density of the base layer

and $\lambda$ is the wavelength of the density measurement.

The densities on the right hand side of Eq. (1) are known as spectral analytical densities. The spectral analytical dye densities can be represented as a parameter times a unit spectral density function for each of the dyes. The dye densities can be written:

$$\begin{aligned} DY(\lambda) &= K_y \cdot Y(\lambda) \\ DM(\lambda) &= K_m \cdot M(\lambda) \\ DC(\lambda) &= K_c \cdot C(\lambda) \end{aligned} \qquad \text{Eq. (2)}$$

where: $Y(\lambda)$, $M(\lambda)$ and $C(\lambda)$ are the unit spectral dye densities for the yellow, magenta and cyan dyes, respectively.
$K_y$, $K_m$ and $K_c$ are the parameters which characterize the amount of dye present in the image. Equation (1) can be rewritten as:

$$D(\lambda) = K_y Y(\lambda) + K_m M(\lambda) + K_c C(\lambda) + DB(\lambda) \qquad \text{Eq. (3)}$$

If the functions $Y(\lambda)$, $M(\lambda)$, $C(\lambda)$ and $DB(\lambda)$ are known, it is possible to determine the parameters $K_y$, $K_m$ and $K_c$ from measurements of the integral density at three different wavelengths. The base density (DB) can be measured at some overexposed portion (positive transparency) or underexposed portion (negative transparency) of the imagery. If the integral density measurements are taken at $\lambda_1$, $\lambda_2$ and $\lambda_3$ (three different wavelengths), three different equations can be generated from Eq. (3). Letting $\Delta D(\lambda) = D(\lambda) - DB(\lambda)$, then:

$$\Delta D(\lambda_1) = K_y Y(\lambda_1) + K_m M(\lambda_1) + K_c C(\lambda_1)$$

$$\Delta D(\lambda_2) = K_y Y(\lambda_2) + K_m M(\lambda_2) + K_c C(\lambda_2) \qquad \text{Eq. (4)}$$

$$\Delta D(\lambda_3) = K_y Y(\lambda_3) + K_m M(\lambda_3) + K_c C(\lambda_3)$$

This set of equations can be solved and the solution is represented as:

$$K_y = C_{11}\Delta D(\lambda_1) + C_{12}\Delta D(\lambda_2) + C_{13}\Delta D(\lambda_3)$$

$$K_m = C_{21}\Delta D(\lambda_1) + C_{22}\Delta D(\lambda_2) + C_{23}\Delta D(\lambda_3) \qquad \text{Eq. (5)}$$

$$K_c = C_{31}\Delta D(\lambda_1) + C_{32}\Delta D(\lambda_2) + C_{33}\Delta D(\lambda_3)$$

Thus, the parameters $K_y$, $K_m$ and $K_c$, can be determined from three integral spectral density measurements if the nine transformation parameters ($C_{jj's}$) are known. The nine transformation parameters are dependent only on the characteristics of the dyes in the film and not on the specific combination of dyes which represent a scene on the imagery. These nine parameters are used in constructing characteristic curves for each dye layer of the film.

Once these parameters of a color or color-infrared film are known, radiometric calibration of the aerial image can take place. The intent of most remote sensing applications of photography is to infer some ground phenomena from a measurement (or interpretation) on the film imagery. It should be noted than film density is not the quantity to be correlated to the reflected energy from the ground. The dye densities formed in films depend--in a nonlinear way--not only on the amount of energy and its spectral distribution striking the unexposed film, but also on the processing of the imagery.

The intent of a radiometric calibration is to derive the relationship between film density (or dye constants) and the light impinging on the unexposed film. This relationship is called a characteristic or K/log E curve. It is called a K/log E curve because for a limited range of exposures (incident energy) there is a near linear relationship between density and the logarithm of the incident energy. An example of such a curve can be found in Fig. II-3. Note there is a different characteristic curve for each layer of the film.

Once a characteristic curve has been generated for a specific roll of imagery, the use of it in the analysis procedure is relatively straightforward. After the analytical densities have been found for a particular spot on the imagery, the characteristic curve is used to find the three exposures (one for each layer) which represent the incident energy at that spot on the unexposed film. These exposures are the values to be correlated with the ground phenomena via the digital analysis programs. In the Menomonee River Pilot

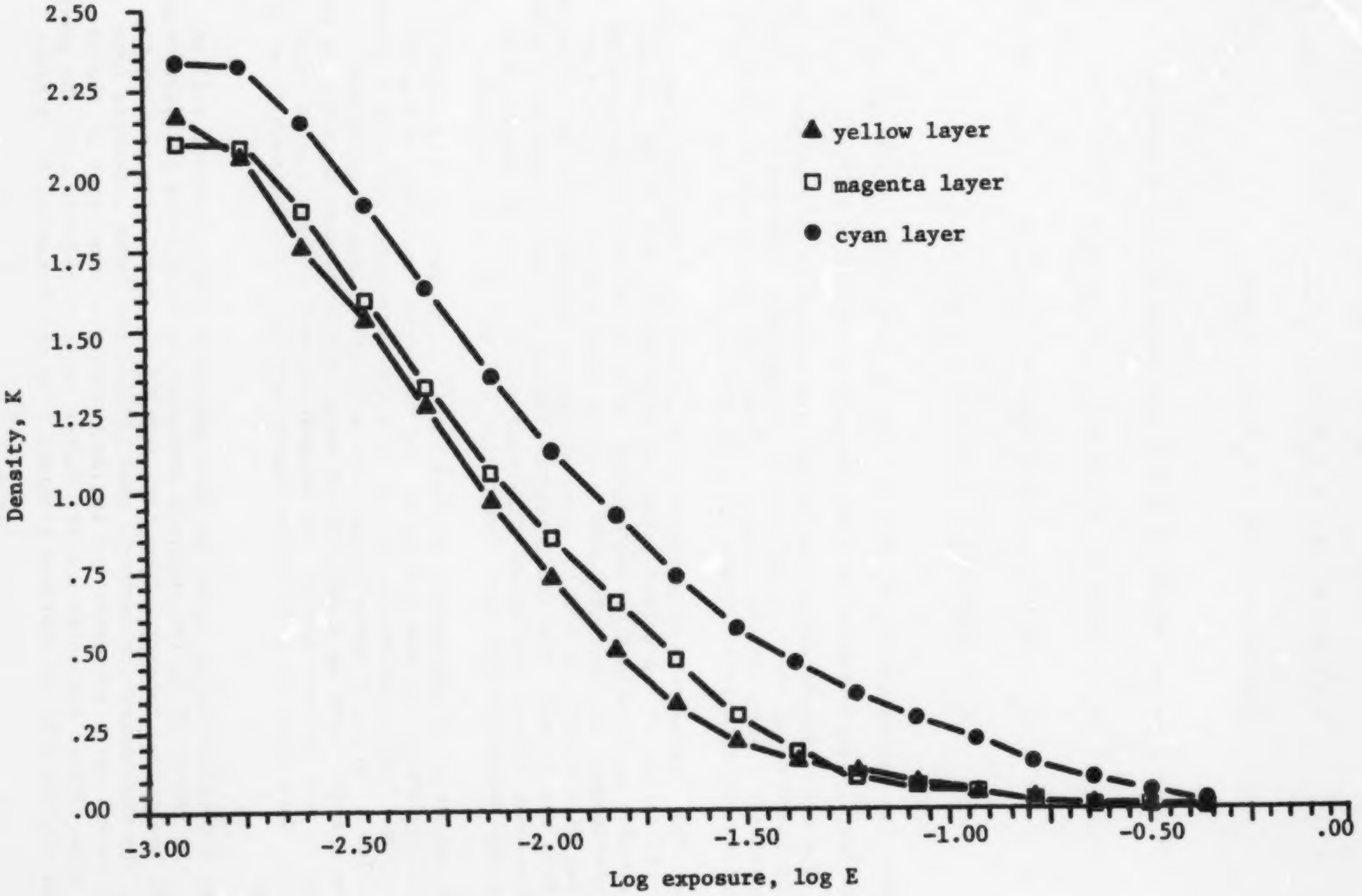

Fig. II-3. Typical K/log E curve for a multi emulsion image.

Watershed Study these values were correlated to land cover.

## Application

In order to test this technique two subwatersheds were chosen in the Menomonee River Basin, namely Schoonmaker and Noyes Creeks. Schoonmaker Creek is a completely developed medium density urban area while Noyes Creek is in the early stages of urbanization. NASA color-infrared imagery--at a scale of 1:120,000--of the areas was digitized on an Optronics P-1700 scanning microdensitometer. The ground resolution for both subwatersheds was 6.0 $m^2$. The computer tapes produced for these areas by the Optronics system were corrected to exposures and placed on disk files. Training areas representing the different land cover categories were chosen in each subwatershed. After the training areas were checked for accuracy, a statistical analysis was performed on them thereby providing the needed statistics for the elliptical classifier.

This type of classifier first creates an ellipsoid in spectral space from the statistics derived for each training area. The classifier then determines if the spectral signature of each pixel falls within the various ellipsoids. If a pixel falls into only one ellipsoid, the pixel is classified as being of that class. If the pixel falls into more than one ellipsoid, the minimum distance to the mean of each ellipsoid is calculated and the pixel is classified to the closest mean. Pixels that do not fit into any of the training area ellipsoids remain unclassified. A schematic of the entire process is shown in Fig. II-4.

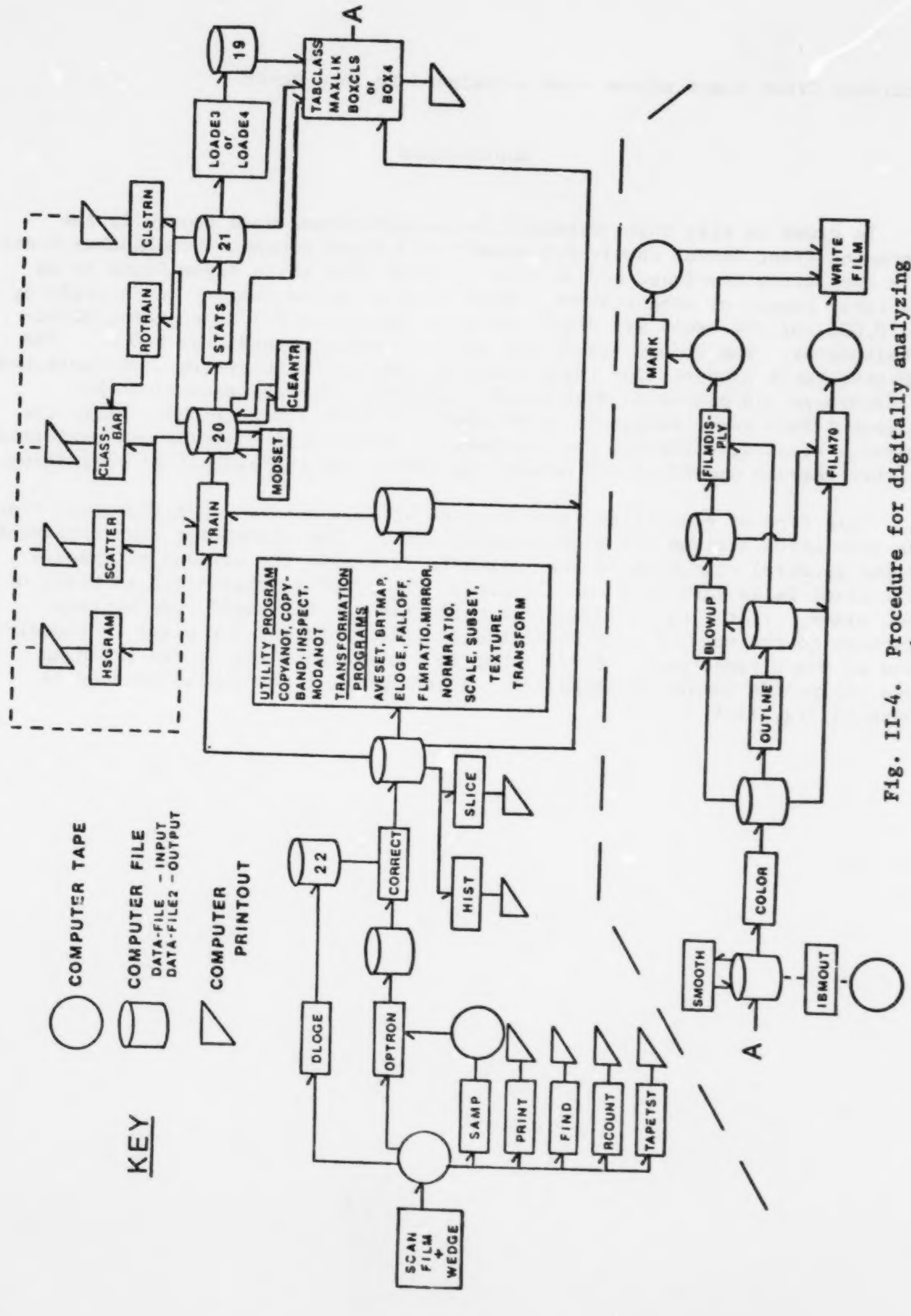
KEY
COMPUTER TAPE
COMPUTER FILE
DATA-FILE - INPUT
DATA-FILE2 - OUTPUT
COMPUTER PRINTOUT
SCAN FILM + WEDGE
DLOGE
OPTRON
SAMP
PRINT
FIND
RCOUNT
TAPETST
22
CORRECT
HIST
SLICE
UTILITY PROGRAM
COPYANOT, COPY-BAND, INSPECT, MODANOT
TRANSFORMATION PROGRAMS
AVESET, BRTMAP, ELOGE, FALLOFF, FLMRATIO, MIRROR, NORMRATIO, SCALE, SUBSET, TEXTURE, TRANSFORM
HSGRAM
SCATTER
CLASS-BAR
TRAIN
20
MODSET
CLEANTR
ROTRAIN
STATS
21
CLSTRN
LOADE3 or LOADE4
19
TABCLASS
MAXLIK
BOXCLS
or
BOX4
A
A
SMOOTH
IBMOUT
COLOR
OUTLNE
BLOWUP
FILMDIS-PLY
FILM70
MARK
WRITE FILM

Fig. II-4. Procedure for digitally analyzing photographic imagery.

## II-4. RESULTS AND DISCUSSION

The results of the classifications for each subwatershed after several iterations are shown in Table II-1. For the computer classifications five major land cover categories were chosen: impervious surfaces; streets, sidewalks, rooftops, etc.; tree cover; vegetative cover; water; and a transition class. This class usually contains a combination of the impervious and vegetative covers and represents boundary conditions between other land cover categories.

Besides a tabular product both color slides and prints were produced of the two classified subwatersheds. A ground check of the classifications showed them to be approximately 90% accurate.

Three other urban watersheds in the Great Lakes Basin were investigated using this technique. Imagery--of Detroit, Michigan and Windsor, Ontario; Toledo, Ohio; and Rochester, New York--was obtained from the EROS Data Center in Sioux Falls, South Dakota. The scale of the imagery was approximately 1:130,000 and each image was digitized on the Optronics system at 50 micron intervals, making the picture element (pixel) approximate an area on the ground of 6.5 $m^2$. Several problems hindered the digital analysis process in these areas. First, film wedges were not available from EROS for any of the imagery. This precluded correction of the digitized data resulting in inaccuracies in classifying land cover. Secondly, watershed and subwatershed coordinates and boundaries within these urban areas were not provided. Therefore, no classifications for actual watersheds or subwatersheds were performed; rather, simulated watershed boundaries were contrived so that the process of classification of land cover within an outlined watershed could at least be practiced and tested. The results of the classification on these areas are presented in Table II-2.

A listing of typical costs for classifying various sets of digitized data within these watersheds is presented in Table II-3. This table includes large data sets as well as smaller subsets (subwatersheds) of data and the cost includes both materials and computer costs.

Table II-1. Land cover classifications for Schoonmaker and Noyes Creeks

| Landcover | Schoonmaker Creek, % | Noyes Creek, % |
|---|---|---|
| Impervious | 63.6 | 38.0 |
| Vegetation | 25.4 | 50.0 |
| Forest | 0 | 3.7 |
| Transition | 10.7 | 3.3 |
| Water | 0 | 0.05 |
| Unclassified | 0.3 | 4.95 |
| | 100 | 100 |

Table II-2. Land cover classifications for selected urban areas in the Great Lakes Basin expressed as percentages

| Cover | Toledo-1 | Toledo-2* | Toledo-3** | Toledo-4** | Windsor-1 | Windsor-2** | Rochester-1 |
|---|---|---|---|---|---|---|---|
| Impervious | 63 | 33 | 67 | 41 | 28 | 14 | 45 |
| Grass | 11 | 0 | 3 | 14 | 28 | 78 | 17 |
| Trees | 20 | 0 | 25 | 33 | 28 |  | 28 |
| Other/ unclassified | 6 | 67 | 5 | 12 | 16 | 8 | 10 |

*Only impervious surfaces were classified.
**Simulated subwatersheds.

Table II-3. Cost estimates for digital analysis of high altitude aircraft imagery for land cover classification (cost/image)

| Process | Cost*, $ | Time, hr |
|---|---|---|
| Obtain film | $15.00 | 0 |
| Scan film/store digitized data on tape | 12.00 | 2 |
| Run OPTRON | 3.00 | 0.5 |
| Orient pixels with image from initial level slice | 1.00 | 1 |
| Create subset of data | 1.50 | 0.25 |
| Create ratio of subsetted data | 1.50 | 0.25 |
| Level slice of ratio (all option)<br>Level slice of ratio (overprint option) | 4.00 | 1 |
| Select training sets from overprinted maps | 0 | 1.5 |
| Run TRAIN, CLASSBAR, and ISGRAM | 2.00 | 1 |
| Select standard deviations for training set ellipsoid | 0 | 1.5 |
| Run LOADE3 and TABCLASS | 3.00 | 0.5 |
| Add more training sets; follow previous two steps (in necessary) | 5.00 | 2 |
| Store final classification | 2.00 | 0.5 |
| Run COLOR | 2.00 | 0.5 |
| Run OUTLINE | 1.50 | 0.5 |
| Run FILM70 for 6 files | 6.50 | 0.5 |
| Make film | 0 | 2.5 |
| Take slides from $I^2S$ | 3.00 | 1 |
| Process slides | 4.00 | 0 |
| TOTAL | $62.00 | 20.0 |

*Includes materials and computer costs

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# PART III

# DESCRIPTION OF THE WATERSHED

by

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# ABSTRACT

The Menomonee River Watershed is described in order to establish a factual base upon which to draw conclusions concerning the interactions of the ecosystem and the impact on water quality. The description includes natural and cultural features such as population, land use, climate, physiography and geology, soils and water storage areas. Also included in the description are the characteristics and management practices existing in the drainage areas of the mainstem and predominantly single land use monitoring sites.

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# III-1. INTRODUCTION

A watershed is a complex of natural and man-made features which interact to comprise a changing environment for all life. The water quality characteristics of the Menomonee River Watershed are primarily a function of the activities of man as he interacts and alters the natural features of the Watershed. A watershed may be viewed as a large ecosystem composed of natural resources, man-made features, and the human and animal populations, all of which interact synergistically to alter the water quality characteristics of the watershed. Of primary concern are the changes in the ecosystem which affect the water quality of the watershed and the final receiving body--Lake Michigan.

Because of the existence of a diversity of land uses in the Menomonee River Watershed, it is well chosen as a study site for determining the impact of man's activities on water quality. Urban land uses range from an intensely-developed commercial-industrial complex in the lower quarter of the Watershed to low to medium-density residential areas in the center half of the Watershed, while the upper quarter is in the process of conversion from rural to urban land use.

The purpose of this Section is to describe the existing ecosystem, thereby establishing a factual base upon which to draw conclusions concerning the interactions of the ecosystem--especially man's activities--and the impact on water quality. Additionally, this information will be used to extrapolate the findings to other urban centers within the Great Lakes Basin.

## III-2. WATERSHED CHARACTERISTICS

### Location

The Menomonee River Watershed, as shown in Fig. III-1, is a surface water drainage unit, 355 $km^2$ in areal extent, discharging to the Milwaukee River in the City of Milwaukee $\sim$ 1.4 km upstream of the entrance of the Milwaukee River to Lake Michigan. The relatively narrow Watershed is bounded on the north and east by the Milwaukee River Watershed; on the south by the Kinnickinnic River, Root River and Oak Creek Watersheds; and on the west by the Rock River and Fox River Watersheds. The western boundary of the Watershed marks the subcontinental separation of the Great Lakes-St. Lawrence River and the Illinois-Mississippi drainage basins.

The Menomonee River has its source in a large woodland wetland area located in the northeastern corner of the Village of Germantown in Washington County. From its source, the river flows southeasterly through the Villages of Germantown and Menomonee Falls into Milwaukee County. It is joined by the Little Menomonee River in the City of Milwaukee near state highway 100 and W. Hampton Avenue, the Little Menomonee River having its source in the City of Mequon in Ozaukee County and flowing southerly through the Cities of Mequon and Milwaukee to its junction with the Menomonee River. From its junction with the Little Menomonee, the Menomonee River flows southeasterly through the Cities of Milwaukee and Wauwatosa to be joined by Underwood Creek near W. North Avenue. Underwood Creek drains portions of the Cities of Wauwatosa, Brookfield, West Allis, and New Berlin, as well as the Village of Elm Grove and the Town of Brookfield. Honey Creek, which drains portions of the Cities of Milwaukee, Wauwatosa, West Allis, and Greenfield and the Village of Greendale, joins the Menomonee River from the south near 72nd Street. From its junction with Honey Creek the Menomonee River continues to flow in a generally southeasterly direction through the Cities of Wauwatosa and Milwaukee, entering the Lake Michigan estuary at a low dam located near N. 29th St. in the City of Milwaukee.

### Population Size and Distribution

The population of the Watershed was estimated at 336,824 in 1975. As shown in Table III-1, the population increased from 1900 to 1970 at rates generally greater than those of the state and nation. During 1970 to 1975, the population decreased by 2% while the state and nation increased by 4%. This decline is attributed to the migration of people from the larger urban centers to suburban-rural areas within and outside of the Watershed. The outward population movement occurred mainly from the cities and villages

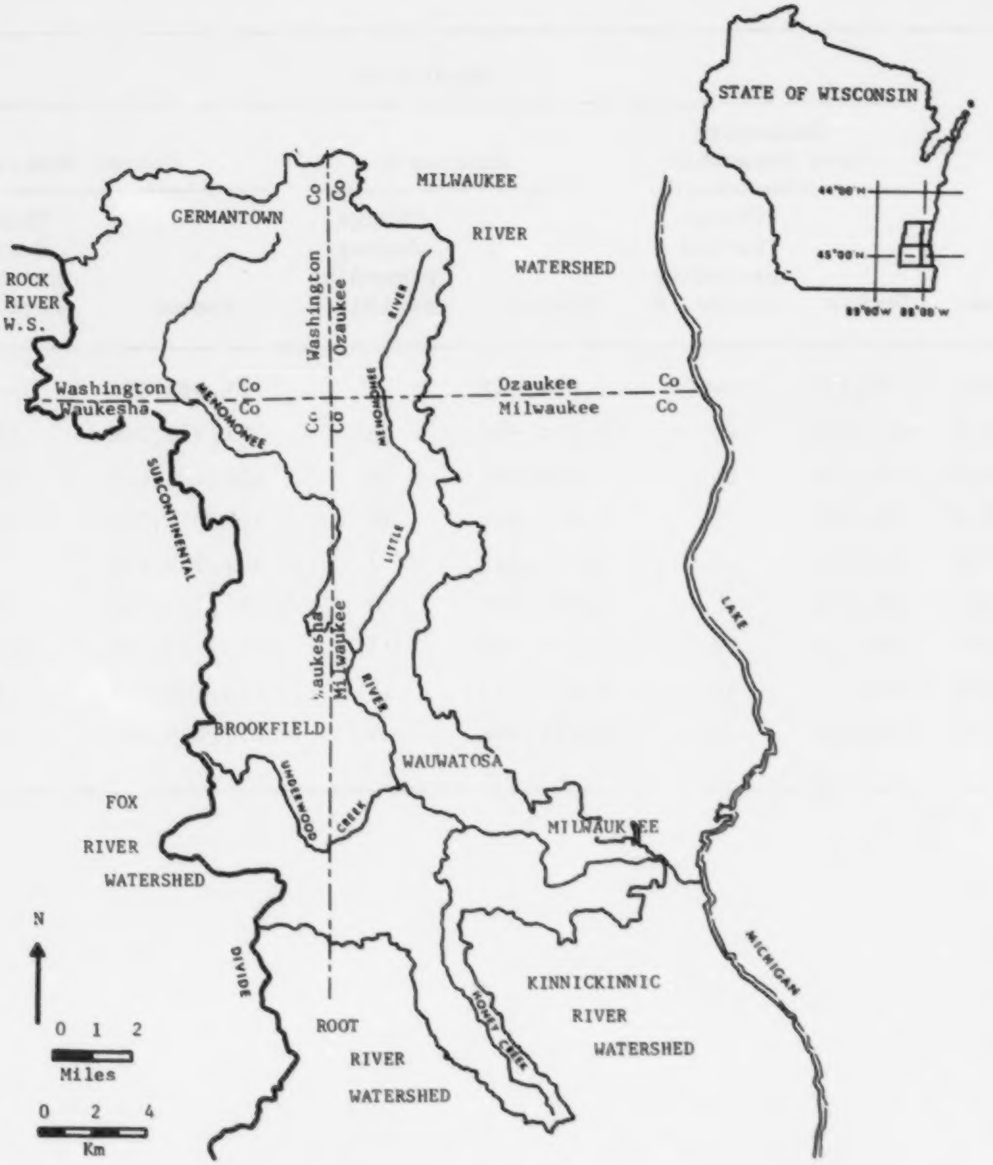
STATE OF WISCONSIN
44°00'N
43°00'N
89°00'W
88°00'W
MILWAUKEE
RIVER
WATERSHED
GERMANTOWN
Washington Co
Ozaukee Co
ROCK
RIVER
W.S.
Washington Co
Waukesha Co
Ozaukee Co
Milwaukee Co
MENOMONEE
MENOMONEE RIVER
LITTLE
SUBCONTINENTAL
Waukesha Co
Milwaukee Co
RIVER
BROOKFIELD
WAUWATOSA
UNDERWOOD
CREEK
FOX
RIVER
WATERSHED
MILWAUKEE
LAKE
MICHIGAN
N
DIVIDE
HONEY CREEK
KINNICKINNIC
RIVER
WATERSHED
ROOT
RIVER
WATERSHED
0 1 2
Miles
0 2 4
Km

Fig. III-1. The Menomonee River Watershed.

Table III-1. Population in the Menomonee River Watershed, Wisconsin and the United States

| | Population | | | | | |
|---|---|---|---|---|---|---|
| | Menomonee River Watershed | | Wisconsin | | United States | |
| Year | Number | Change during preceding period, % | Number | Change during preceding period, % | Number | Change during preceding period, % |
| 1900 | 94,917 | -- | 2,069,042 | -- | 75,994,575 | -- |
| 1910 | 122,275 | 29 | 2,333,860 | 13 | 91,972,266 | 21 |
| 1920 | 151,271 | 24 | 2,632,067 | 13 | 105,710,620 | 15 |
| 1930 | 200,403 | 32 | 2,939,006 | 12 | 122,775,046 | 16 |
| 1940 | 213,295 | 6 | 3,137,587 | 7 | 131,669,270 | 7 |
| 1950 | 240,006 | 12 | 3,434,575 | 9 | 151,325,798 | 15 |
| 1960 | 309,121 | 29 | 3,952,771 | 15 | 179,323,175 | 18 |
| 1970 | 344,614 | 12 | 4,417,933 | 12 | 203,184,772 | 13 |
| 1975 | 336,824 | -2 | 4,581,701 | 4 | 212,245,000 | 4 |

of Milwaukee County (Table III-2). All other counties and civil divisions, except the Village of Butler, showed a population increase. In 1975, population density of the Watershed was 949 people/km$^2$, however, some 80% of the population resides in the lower portion of the Watershed in Milwaukee County, and the remaining 20% in the urbanizing areas of Ozaukee, Washington and Waukesha Counties. During the last two decades, the average population density of the Watershed has increased > 40% causing aggrevated water quality problems.

## Land Use and Land Cover

### General

The Land Data Management System (Land DMS) developed by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) provides for 79 land use descriptions (1). Table III-3 lists land use descriptions and associated computer codes and Watershed percentage and area in each land use for 1975. It should be noted that the Land DMS does not contain information on land cover, such as the area covered by impervious surfaces. Land cover information must be obtained from other sources or estimated from the particular land uses in the area under study.

The 79 land use descriptions have been consolidated into 14 land use categories (Table III-4). The consolidation groups similar land uses and land uses that have similar potential for non-point pollution. The 14 land use categories for 1970 and 1975--with Watershed area and percent distribution--are presented in Table III-5. The increase in urban land use during the 5-yr period is a continuing reflection of the historic growth within the Watershed (Fig. III-2). The predominantly urban characteristics of the Watershed are clearly evident as is the pattern of historic growth from the lower to the upper parts of the Watershed. The dominant urban land use in the Watershed is residential and encompasses 9,087 ha, or approximately 26% of the total Watershed area. Most of the larger contiguous non-urbanized lands are located in Washington and Ozaukee Counties with small parcels of rural lands remaining in the northeastern corner of Waukesha County and the northwest corner of Milwaukee County.

Figure III-3 and Table III-6 show the location and associated land uses for the monitoring stations in the Watershed. Table III-6 allows a rapid evaluation of the distribution of the different land uses at each monitoring station. It should be noted that the first three stations are aggregated under one land use breakdown since land uses were not determined for each of the stations. Summation of the individual land use totals for the first 15 stations equal approximately the total area of the Watershed. The remaining stations are contained in the drainage areas of the first group. The drainage areas of the first 15 monitoring stations range in size from a maximum of 6,657 ha to a minimum of 179 ha with an average of 2,713 ha, allowing an initial segmentation of the Watershed into 13 sub-basins.

Table III-2. Population in the Menomonee River Watershed by county and civil division

| Civil division* | Population 1950 | Population 1960 | Population 1970 | Population 1975 |
|---|---|---|---|---|
| **Milwaukee County** | | | | |
| Cities | | | | |
| Greenfield | --- | 4,753 | 6,892 | 8,752 |
| Milwaukee | 135,808 | 157,953 | 168,201 | 159,819 |
| Wauwatosa | 33,324 | 56,923 | 58,676 | 55,712 |
| West Allis | 23,572 | 39,556 | 40,815 | 38,753 |
| Villages | | | | |
| Brown Deer** | --- | 1,572 | --- | --- |
| Greendale | 90 | 223 | 492 | 495 |
| West Milwaukee | 4,072 | 4,301 | 3,757 | 3,230 |
| Towns | | | | |
| Granville | 2,418 | --- | --- | --- |
| Greenfield | 7,560 | --- | --- | --- |
| Wauwatosa | 19,153 | --- | --- | --- |
| Sub total | 225,997 | 265,281 | 278,833 | 266,761 |
| **Ozaukee County** | | | | |
| City | | | | |
| Mequon | --- | 1,337 | 1,901 | 2,026 |
| Town | | | | |
| Mequon | 615 | --- | --- | --- |
| Sub total | 615 | 1,337 | 1,901 | 2,026 |
| **Washington County** | | | | |
| City | | | | |
| Milwaukee | --- | --- | --- | 2 |
| Village | | | | |
| Germantown | 357 | 622 | 6,754 | 8,317 |
| Town | | | | |
| Germantown | 2,005 | 3,804 | 370 | 375 |
| Richfield | 89 | 152 | 254 | 383 |
| Sub total | 2,451 | 4,578 | 7,378 | 9,077 |
| **Waukesha County** | | | | |
| Cities | | | | |
| Brookfield | --- | 13,354 | 18,387 | 18,934 |
| New Berlin | --- | 1,697 | 2,609 | 2,657 |
| Villages | | | | |
| Butler | 1,047 | 2,274 | 2,261 | 2,230 |
| Elm Grove | --- | 4,994 | 7,201 | 7,692 |
| Menomonee Falls | 2,469 | 15,469 | 25,829 | 27,233 |
| Towns | | | | |
| Brookfield | 4,491 | 130 | 174 | 173 |
| Lisbon | 4 | 7 | 41 | 41 |
| Menomonee | 2,450 | --- | --- | --- |
| New Berlin | 482 | --- | --- | --- |
| Sub total | 10,943 | 37,925 | 56,502 | 58,960 |
| Total, Menomonee River Watershed | 240,006 | 309,121 | 344,614 | 336,824 |

*The list of civil divisions in the Watershed and the boundaries of these civil divisions have changed over time because of incorporations and annexations.

**The Village of Brown Deer incorporated from parts of the Town of Granville between 1950-1960; after 1960, the City of Milwaukee attached the Village of Brown Deer.

Table III-3. Land use description and area and percent of each use in the Menomonee River Watershed for 1975

| Land use description | 3 digit SEWRPC code | Area, ha | % of watershed |
|---|---|---|---|
| Residential | | | |
| Single family on lots < 2 ha (non farm) | 111 | 7,958.41 | 22.56 |
| Single family associated with farm building | 113 | 3.09 | 0.01 |
| Single family on lots > 2 ha (non farm) | 112 | 74.84 | 0.21 |
| Two-family residential | 120 | 471.49 | 1.34 |
| Multi-family high rise (4 or more stories) | 142 | 7.37 | 0.02 |
| Multi-family low rise (1 to 40 stories) | 141 | 401.18 | 1.14 |
| Mobile homes | 150 | 19.94 | 0.06 |
| Residential land under development | 199 | 710.88 | 2.02 |
| Retail sales and service | | | |
| Local retail and service | 210 | 548.76 | 1.56 |
| Regional retail and service | | | |
| Industrial | | | |
| Wholesaling--wholesale structures (food and related, drug and medical, apparel, paper and apparel, paper and paper products, furniture and household wares, not large furniture stores or discount houses); auto salvage yard, junkyards, lumber yards, (not including retail structure on site). | 340 | 82.00 | 0.23 |
| Storage--motor vehicle storage, fuel products (oil tank farms, large coal storage areas), chemical and allied products (large salt storage areas), stockyards, grain elevators, enclosed storage buildings. | 380 | 371.06 | 1.05 |
| Manufacturing | 310 | 450.76 | 1.28 |
| Extractive (quarries and mining) | 360 | 161.15 | 0.46 |
| Transportation | | | |
| Bus terminal | 425 | 1.67 | 0.00 |
| Rail terminal | 445 | 20.78 | 0.00 |
| Ship terminal | 485 | 0.00 | 0.00 |
| Railroad right-of-way | 441 | 320.76 | 0.91 |
| Railroad yards | 443 | 159.59 | 0.45 |
| Air terminal and hangers | 465 | 6.75 | 0.02 |
| Air field | 463 | 143.31 | 0.41 |
| Land access and collector streets | 418 | 2,333.80 | 6.62 |
| Standard arterial street and expressway | 414 | 680.93 | 1.93 |
| Freeway | 411 | 658.60 | 1.87 |
| Truck terminal | 426 | 82.97 | 0.24 |
| Off-street parking | 430 | 790.20 | 2.24 |
| Communication and utilities | 510 | 335.94 | 0.95 |
| Governmental and institutional | | | |
| Local administrative, safety, assembly --city, village, town; post offices (except Milwaukee central), military installations, police stations, union halls, churches, all administrative buildings under city, village, or town authority (i.e. town hall). | 611 | 122.75 | 0.35 |
| Regional administrative, safety, assembly --county, state, federal, prisons and jails, arenas, exposition and convention centers, auditoriums, all administrative buildings under county, state or federal authority (i.e. social security offices, county courthouse). | 612 | 195.56 | 0.55 |
| Local educational--all libraries (except Milwaukee, Racine and Kenosha main), day care centers, nurseries, kindergarten, elementary and junior high schools. | 641 | 305.97 | 0.87 |
| Regional educational--senior high (and junior high combination) schools, colleges (2 and 4 year), technical schools and specialty trade schools, museums, main libraries, (Milwaukee). | 642 | 186.90 | 0.53 |
| Local health--clinics | 661 | 4.67 | 0.01 |
| Regional health--hospitals, nursing homes, group quarters | 662 | 318.32 | 0.90 |
| Local cemeteries--< 2 ha | 681 | 15.01 | 0.04 |
| *Regional cemeteries--> 2 ha* | 682 | | |

Table III-3 (continued).

| Land use description | 3 digit SEWRPC code | Area, ha | % of watershed |
|---|---|---|---|
| Recreation | | | |
| Public cultural-special recreation areas--arboretum, zoo, conservatory, planetarium, botanical garden, stadium, Mitchell domes. | 711 | 52.06 | 0.15 |
| Private cultural special recreation areas (as above) | 712 | 1.52 | 0.00 |
| Public land related recreation areas (see list) | 731 | 1,227.41 | 3.48 |
| Private land related recreation areas (as above) | 732 | 285.39 | 0.81 |
| Public water related recreation areas--beaches, boat launching sites, marinas, fishing piers. | 781 | 0.73 | 0.00 |
| Private water related recreation areas | 782 | 6.68 | 0.02 |
| Agricultural | | | |
| Row crops | 811 | 3,763.82 | 10.67 |
| Grain crops | 812 | 988.75 | 2.80 |
| Vegetable crops | 813 | 1,041.87 | 2.95 |
| Hay | 814 | 1,824.80 | 5.17 |
| Pasture | 815 | 2,439.70 | 6.92 |
| Farm building (no associated animal husbandry) | 871 | 149.59 | 0.42 |
| Farm building with associated animal husbandry-beef cattle | 872 | 4.17 | 0.01 |
| Farm building with associated animal husbandry--dairy cattle | 873 | 27.55 | 0.08 |
| Farm building with associated animal husbandry--horse | 874 | 1.64 | 0.00 |
| Farm building with associated animal husbandry--fowl (chicken, turkey, duck) | 875 | 1.28 | 0.00 |
| Farm building with associated animal husbandry--fur (fox, mink) | 876 | 0.00 | 0.00 |
| Farm building with associated animal husbandry--hogs | 877 | 0.62 | 0.00 |
| Farm building with associated animal husbandry--sheep | 878 | 0.00 | 0.00 |
| Farm building with associated animal husbandry--goats | 879 | 0.00 | 0.00 |
| Orchard and nurseries | 820 | 194.66 | 0.55 |
| Sod farm | 841 | 36.85 | 0.10 |
| Berry fields | 842 | 1.02 | 0.00 |
| Bee hives | 849 | | |
| Natural areas and other open lands | | | |
| Lake, rivers, streams, canals | 950 | 185.20 | 0.53 |
| General wetlands | 910 | 1,068.21 | 3.03 |
| Wetland on residential lots with structures (1.2-2.0 ha) | 913 | 0.21 | 0.00 |
| Wetland on residential lots with structures (> 2 ha) | 914 | 0.00 | 0.00 |
| Wetland on residential lots committed to residential structures | 915 | 1.03 | 0.00 |
| Unused urban land | 921 | 1,037.16 | 2.94 |
| Unused rural land | 922 | 588.17 | 1.67 |
| Unused land on residential lots with structures (1.2-2.0 ha) | 923 | 64.43 | 0.18 |
| Unused land on residential lots with structures (> 2 ha) | 924 | 3.08 | 0.01 |
| Unused land on residential lots committed to res. structures | 925 | 0.00 | 0.00 |
| Retail sales and services under development | 299 | 6.02 | 0.02 |
| Industrial land under development | 399 | 194.48 | 0.55 |
| Transportation land under development | 499 | 0.00 | 0.00 |
| Communication and utility land under development | 599 | 0.00 | 0.00 |
| Government and institutional land under development | 699 | 9.96 | 0.01 |
| Recreational land under development | 799 | 0.00 | 0.00 |
| Land fill and dumps | 930 | 119.80 | 0.34 |
| General woodlands | 940 | 1,747.33 | 4.95 |
| Woodlands on residential lots with structures (1.2-2.0 ha) | 943 | 20.47 | 0.06 |
| Woodlands on residential lots with structures (> 2 ha) | 944 | 6.42 | 0.02 |
| Woodlands on residential lots committed to residential structures | 945 | 0.00 | 0.00 |

Table III-4. Listing of the land use codes consolidated into 14 land use categories

| Land use category | Land use code |
|---|---|
| 1 | 310, 360 |
| 2 | 210, 340, 380 and 425 to 510 |
| 3 | 411, 414, 418 |
| 4 | 141, 142, 150 |
| 5 | 111, 120 |
| 6 | 112, 113, 871, 874, 875, 876, 878 and 879 |
| 7 | 199, 299, 399, 699 and 799 |
| 8 | 811, 813 |
| 9 | 812, 814, 815, 611 to 682, 711 to 782, 841, 842, 849 and 921 to 925 |
| 10 | 820 and 940 to 945 |
| 11 | 910 to 915 |
| 12 | 872, 873 and 877 |
| 13 | 930 |
| 14 | 950 |

Table III-5. Urban and rural land uses inventories for the Menomonee River Watershed in 1970 and 1975 as determined by the S.E. Wisconsin Regional Planning Commission

| Land use category | Land use description | Area**, ha | | % of Watershed | |
|---|---|---|---|---|---|
| | | 1970 | 1975 | 1970 | 1975 |
| | Urban Land Uses | | | | |
| 1. Industrial | Manufacturing and extractive | 588 | 612 | 1.67 | 1.75 |
| 2. Commercial* | Retail, wholesale, service, communication, utilities, transportation and off street parking excluding roads | 2,517 | 2,864 | 7.15 | 8.17 |
| 3. Roads | Freeways, standard arterial streets and expressways and local and collector streets | 4,095 | 3,671 | 11.65 | 10.48 |
| 4. High-density residential | Multi-family and mobile homes | 332 | 428 | 0.94 | 1.22 |
| 5. Medium-density residential | Single family and two family dwellings | 7,486 | 8,430 | 21.29 | 24.06 |
| 6. Low-density residential | Single family dwellings on lots > 2 ha and all farm buildings except feed lots | 139 | 230 | 0.40 | 0.66 |
| 7. Land under development | All types of land | 1,023 | 921 | 2.91 | 2.63 |
| Sub total - urban | | 16,180 | 17,156 | 46.01 | 48.97 |
| | Rural Land Uses | | | | |
| 8. Row crops | Row crops and vegetables | 5,491 | 4,806 | 15.62 | 13.71 |
| 9. Pastures and small grains* | Grain crops, hay, pasture, park and recreational land, governmental and institutional and unused land | 10,533 | 9,705 | 29.95 | 27.69 |
| 10. Forested land wood lots | Woodlands, orchards and nurseries | 1,677 | 1,969 | 4.77 | 5.62 |
| 11. Wetlands | Swamps, marshes and wetlands | 997 | 1,069 | 2.84 | 3.05 |
| 12. Feedlots | Feedlots | 39 | 32 | 0.11 | 0.09 |
| 13. Landfill and dumps | Landfills and dumps | 101 | 120 | 0.29 | 0.34 |
| 14. Water areas | Lakes, rivers, streams and canals | 143 | 185 | 0.41 | 0.53 |
| Sub total - rural | | 18,983 | 17,886 | 53.99 | 51.03 |
| Total - watershed | | 35,163 | 35,044 | 100.00 | 100.00 |

*In the Menomonee River Watershed most governmental and institutional buildings are associated with large open parklands and are included in Category 9. In other watersheds, where these buildings are associated with a commercial district, they are better included in Category 2.

**The 1975 data are more accurate because hectare-sized cells were summed; 1970 data were based on 0.65 km$^2$ cells.

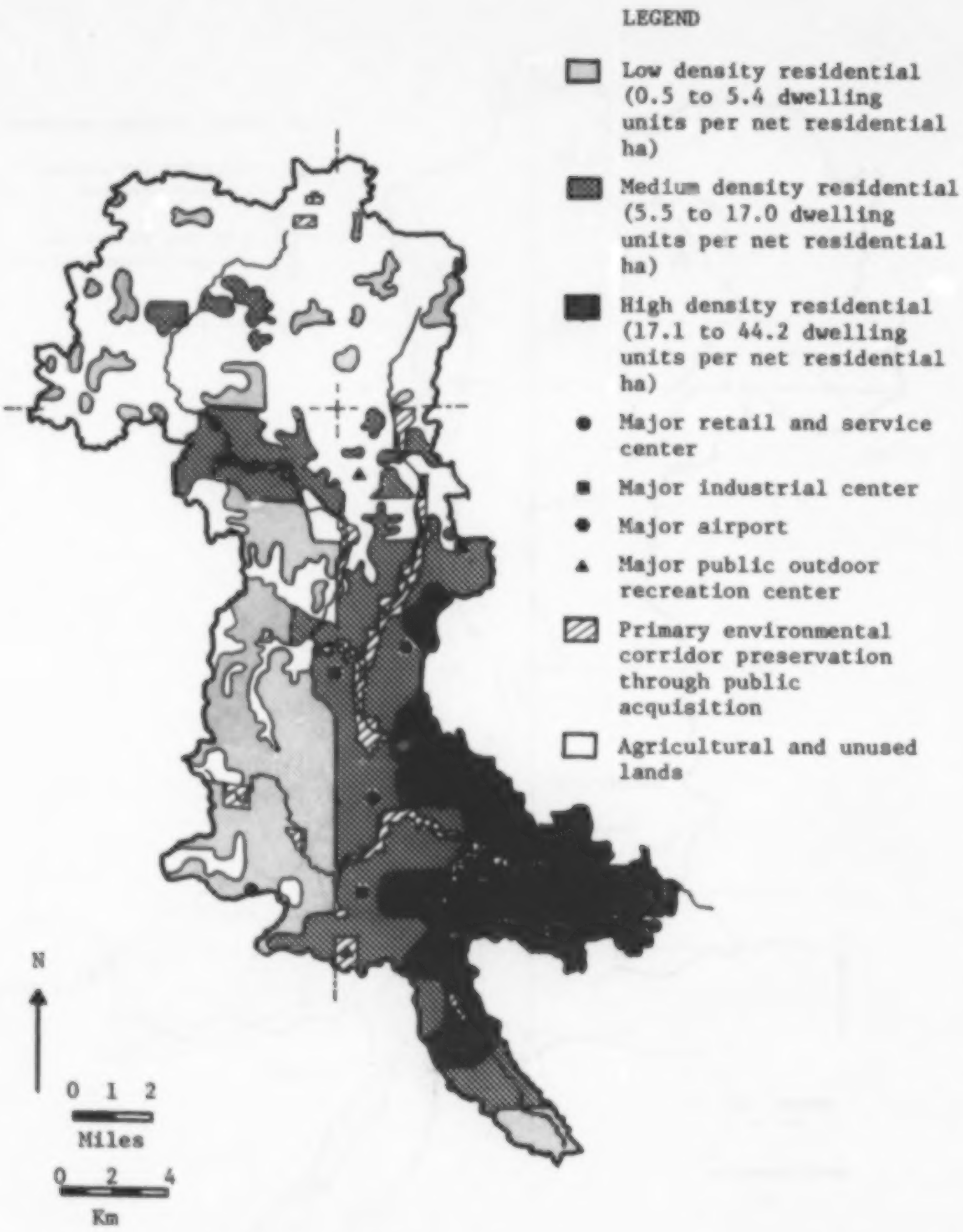
LEGEND
▢ Low density residential (0.5 to 5.4 dwelling units per net residential ha)
▩ Medium density residential (5.5 to 17.0 dwelling units per net residential ha)
■ High density residential (17.1 to 44.2 dwelling units per net residential ha)
● Major retail and service center
■ Major industrial center
● Major airport
▲ Major public outdoor recreation center
▨ Primary environmental corridor preservation through public acquisition
☐ Agricultural and unused lands
N
0 1 2
Miles
0 2 4
Km

Fig. III-2. Generalized land use in the Menomonee River Watershed, 1975.

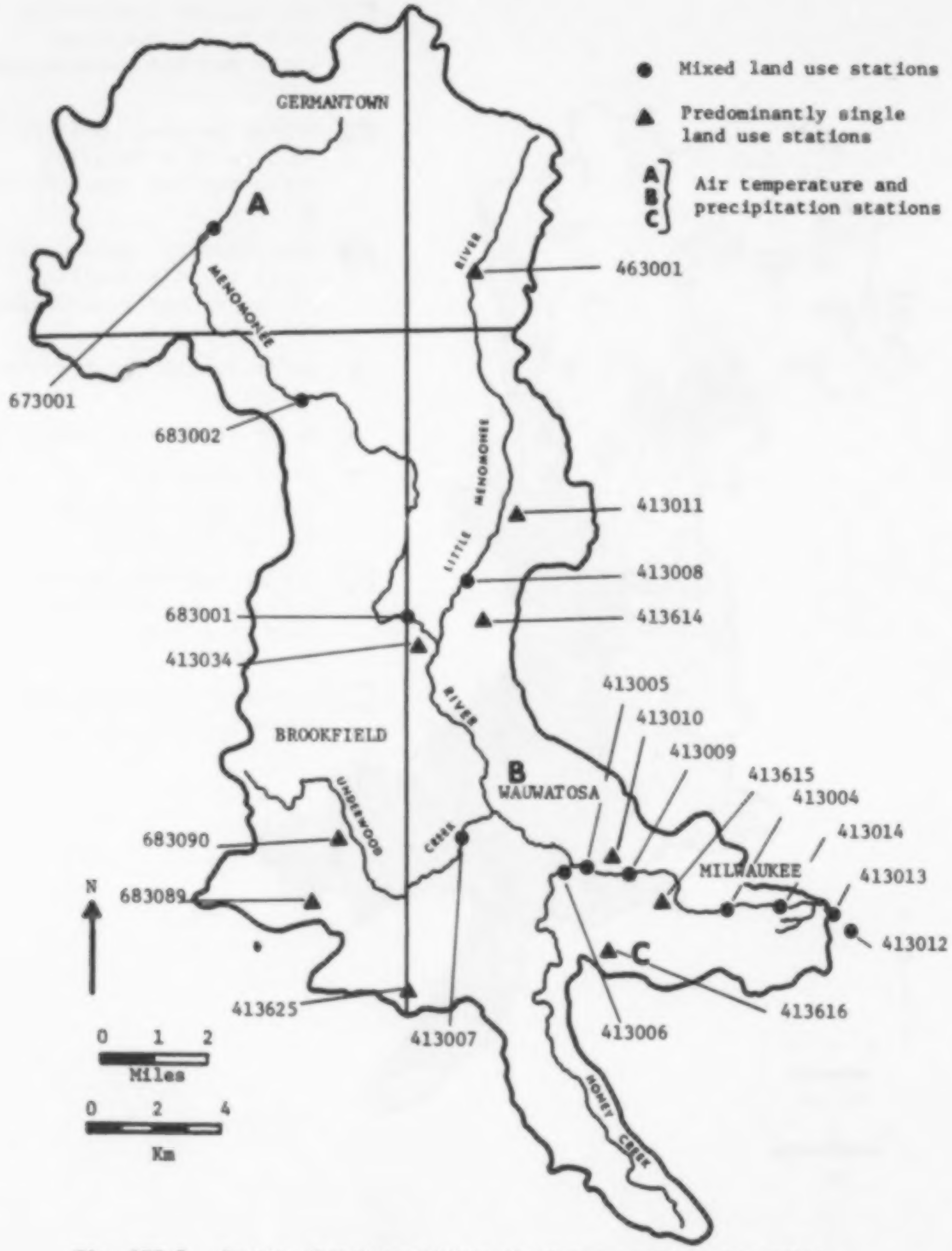
● Mixed land use stations
▲ Predominantly single land use stations
A B C Air temperature and precipitation stations
GERMANTOWN
A
MENOMONEE
RIVER
463001
673001
683002
LITTLE MENOMONEE
413011
413008
683001
413614
413034
RIVER
413005
413010
BROOKFIELD
413009
B
413615
WAUWATOSA
413004
UNDERWOOD
CREEK
683090
413014
MILWAUKEE
N
683089
413013
413012
C
413625
413616
413007
413006
0 1 2
Miles
0 2 4
Km
HONEY CREEK

Fig. III-3. Station locations within the Menomonee River Watershed.

Table III-6. Menomonee River Watershed monitoring stations* with area for each land use category: 1975

| STORET number | Location of monitoring station | Land use category,** ha | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total |
| 413012 | Harbor at Hwy. 32 bridge | 60 | 272 | 227 | 41 | 144 | 0 | 7 | 0 | 95 | 0 | 0 | 0 | 0 | 28 | 874 |
| 413013 | Menomonee River (MR) at 2nd St. bridge | | | | | | | | | | | | | | | |
| 413014 | MR at W. 13th St. bridge | | | | | | | | | | | | | | | |
| 413004 | MR above 27th St. at Falk Corporation | 133 | 404 | 397 | 30 | 538 | 1 | 4 | 0 | 293 | 0 | 0 | 0 | 14 | 15 | 1,829 |
| 413009 | MR at Hawley Road | 0.04 | 11 | 52 | 3 | 94 | 0 | 0.2 | 0 | 21 | 0 | 0 | 0 | 0 | 0 | 181 |
| 413005 | MR at 70th St. bridge | 105 | 671 | 668 | 94 | 1,117 | 0.5 | 27 | 11 | 1,083 | 24 | 0 | 0 | 2 | 34 | 3,836 |
| 413006 | Honey Creek 140 m above confluence with MR | 24 | 237 | 541 | 91 | 1,262 | 0.4 | 49 | 15 | 524 | 14 | 9 | 0 | 13 | 4 | 2,783 |
| 413007 | Underwood Creek above Hwy. 45 off North Ave. | 76 | 446 | 567 | 53 | 1,967 | 7 | 145 | 29 | 1,297 | 193 | 138 | 0 | 40 | 12 | 4,970 |
| 683001 | MR at 124th St. (Hwy. M) | 106 | 348 | 500 | 11 | 1,690 | 54 | 302 | 938 | 2,157 | 331 | 164 | 3 | 22 | 31 | 6,657 |
| 413008 | Little MR at Appleton Ave. (Hwy. 175) | 26 | 176 | 160 | 46 | 316 | 19 | 120 | 389 | 891 | 200 | 99 | 0.4 | 13 | 7 | 2,462 |
| 683002 | MR at Pilgrim Road (Hwy. YY) | 27 | 84 | 258 | 12 | 633 | 48 | 130 | 864 | 1,250 | 368 | 331 | 3 | 1 | 16 | 4,025 |
| 673001 | MR at River Lane Road (Hwy. F) | 44 | 101 | 118 | 25 | 233 | 66 | 80 | 1,621 | 1,542 | 626 | 281 | 14 | 0 | 22 | 4,773 |
| 463001 | Donges Bay Road, Mequon | 0 | 16 | 40 | 1 | 149 | 33 | 34 | 938 | 648 | 210 | 49 | 12 | 0 | 14 | 2,144 |
| 413010 | Schoonmaker Creek at Vliet St. | 0 | 8 | 40 | 1 | 118 | 0 | 3 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 179 |
| 413011 | Hoyes Creek at 91st St. | 10 | 83 | 109 | 21 | 167 | 1 | 15 | 1 | 126 | 2 | 0.4 | 0 | 15 | 2 | 552 |
| 413625 | City of New Berlin at 124th St. and Greenfield Ave. | 0 | 6 | 25 | 2 | 0 | 127 | 6 | 0 | 56 | 2 | 0 | 0 | 0 | 0 | 224 |
| 683090 | Village of Elm Grove, ditch at Underwood Pkwy. | 0 | 3 | 17 | 0 | 0 | 131 | 6 | 0 | 5 | 4 | 0 | 0 | 0 | 0 | 166 |
| 413614 | Timmerman Airport, manhole #6 | 0 | 134 | 5 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 140 |
| 413615 | Stadium interchange, I-94, manhole #120 | 0 | 9 | 26 | 0 | 11 | 0 | 0.1 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 64 |
| 683089 | Brookfield Square Shopping Center | 0 | 37 | 3 | 0 | 5 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 61 |
| 413034 | City of Wauwatosa, off Ferrick St. | 25 | 54 | 9 | 0 | 8 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 110 |
| 413616 | Allis-Chalmers Corp., City of West Allis | 38 | 10 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49 |

*The harbor stations, numbers 413012, 413013 and 413014 are grab sampling stations. The remaining stations are automatic sampling and continuous flow monitoring except station number 413004 which is automatic sampling only.

**Land use categories are defined in Table III-5.

For purposes of mainstem monitoring, the Watershed was divided into 7 sub-basins for the following reasons:

1. The harbor sites (413012, 413013 and 413014) were only grab sampling stations.

2. The Hawley Road site (413009) received drainage from a combined sewer system.

3. The station at Falk Corporation (413004), although included in the succeeding discussion, was affected by seiche, thus monitored data were inaccurate. For this reason, the 70th Street station (413005) was used to integrate the non-point pollutional land arising from the entire Watershed.

4. Although stations 463001, 413011 and 413010 were on the mainstem or tributary stream, they monitor essentially single land uses, hence they are included with the other predominantly single land use sites--413625, 683090, 413614, 413615, 683089, 413034 and 413616--which are discussed later.

## Mainstem and tributary stream monitoring stations

The Menomonee River Watershed was divided into eight tributary areas by utilizing eight automatic monitoring stations on the mainstem of the Menomonee River and major tributary streams (Fig. III-3). Mainstem stations were assigned STORET numbers 673001, 683002, 683001, 413005 and 413004 and tributary streams were 413009, 413007 and 413006. During 1975 the average flow for stations 413008, 413007 and 413006 was 0.48, 0.40 and 0.23 $m^3$/sec, respectively, while the mainstem station 413005 was 3.03 $m^3$/sec. As stations 413004 and 413005 were situated in the lower portion of the Watershed the loading values obtained from these monitoring sites represented loadings from the entire Watershed. Tributary areas ranged in size from 2,803 to 34,398 ha and encompassed a variety of land uses, thus providing integrated pollutant loading values. The tributary areas for the eight monitoring stations were selected so that comparisons could be made with small homogeneous tributary areas.

Four sewage treatment plants (STP) with average discharge of ~ 3800 $m^3$/day are located upstream from station 673001 (1 STP), 683001 (3 STP) and 413005 (4 STP). Results of the 1975 land use inventory are summarized in the form of 14 aggregated land uses for the eight tributary areas (Table III-6). It is important to note that roads were not included in any land use categories except category 3. All roads except category 3 were distributed proportionally among the land use categories. Area directly tributary to a station was defined by the natural watershed boundaries and the highest contour next to the upstream station. For example, station 413005 integrates 29,506 ha of the Watershed but only 3,836 ha lie within the immediate subwatershed of that station.

Examination of land uses for the Watershed show the historical urban development from the harbor section to upstream portions of the Watershed. Most of the commercial and industrial development occurs in the lower one-third of the Watershed and even though medium and high density residential areas are to be found throughout the Watershed, their accumulation is much more pronounced in the lower half (Table III-6). Agricultural land uses are confined almost entirely to the upper portion of the Watershed. It is hoped that variations in pollutant loading at the mainstem stations can be accounted for on the basis of differences in land use distribution.

Based on the 1975 land use inventory SEWRPC was able to determine the extent of imperviousness for each area tributary to a mainstem station (Table III-7). As expected from the land use distribution degree of imperviousness was much more pronounced in the lower half of the Watershed. By a summation from individual land use category data it was possible to determine that portion of the impervious area which was directly connected to a channel (Table III-7). It should be noted that the extent of impervious area directly connected to a channel was closely related to the water load (flow) for each tributary area.

Based on verbal communication with City employees and with staff members of SEWRPC, it was determined that urban areas in the Watershed usually were well maintained. Building exteriors are generally in good condition and laws are well maintained in residential areas. The Watershed does not contain large areas of slums based on buildings being in a rundown condition. Debris tended to be more prevalent around industrial and manufacturing sites than in medium and low density residential areas. Roadways are paved and generally in good repair. Street salting was performed as often as thirty to fifty times during the winter of 1975-1976.

The practice of street sweeping appears to be more prevalent in areas of high population density. Highest sweeping frequency was found in the Cities of Milwaukee, Wauwatosa and West Allis. Rural roadways in municipalities in the upper portion of the Watershed frequently were not included in the sweeping program. By determination of curb km (street km x 2) in each municipality the relative frequency of street sweeping was estimated (Table III-7), e.g., streets were swept 0 to 2 times per year in areas tributary to stations 673001, 683001, 683002 and 413007 while in areas tributary to stations 413006 and 413008 most streets were swept on a weekly basis. The central business districts had relatively high sweeping frequencies. The large municipalities had some method of leaf collection in the fall to supplement their street sweeping activities.

## Predominantly single land use monitoring stations

Ten monitoring stations were established in the Watershed to assess storm water pollution from drainage areas which are predominantly in one land use. Table III-8 provides information on the 10 drainage areas and some of this information is not contained in the Land DMS. The area of impervious surfaces and the percent of impervious area connected directly to a channel are

Table III-7. Characteristics and some management practices in the mainstem monitoring drainage areas

| Category | STORET number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 413004 | 413005 | 413006 | 413007 | 413008 | 683001 | 683002 | 673001 |
| Area adjacent to monitoring station, ha | 1,829 | 3,836 | 2,783 | 4,970 | 2,462 | 6,657 | 4,025 | 4,773 |
| Total imperviousness: | | | | | | | | |
| Area, ha | 1,196 | 1,805 | 1,257 | 1,412 | 378 | 1,096 | 485 | 255 |
| % | 65 | 47 | 45 | 28 | 15 | 16 | 12 | 5 |
| Connected imperviousness: | | | | | | | | |
| Area, ha | 833 | 1,046 | 778 | 348 | 144 | 222 | 126 | 41 |
| % | 46 | 27 | 28 | 7 | 6 | 3 | 3 | 1 |
| Curb length,* km | n.a. | 353 | 322 | 424 | 190 | 289 | 141 | 84 |
| Municipalities adjacent to monitoring station | Milwaukee | Butler<br>Milwaukee<br>Brookfield<br>Wauwatosa | West Allis<br>Wauwatosa<br>Milwaukee<br>Greenfield | Brookfield<br>Elm Grove<br>West Allis<br>Wauwatosa<br>New Berlin | Mequon<br>Milwaukee | Menomonee Falls<br>Butler<br>Brookfield<br>Milwaukee | Germantown<br>Menomonee Falls | Germantown |

Sweeping operations:

| | |
|---|---|
| Germantown<br>Mequon<br>Elm Grove<br>New Berlin | No sweeping in central business, residential, commercial or industrial areas; no leaf pickup in fall. |
| Greenfield - | No sweeping in central business, residential, commercial or industrial areas; leaf pickup in fall. |
| Menomonee Falls - | Weekly sweeping in central business district; semi-annual sweeping in residential, commercial or industrial areas; leaf pickup in fall. |
| Butler - | Semi-annual sweeping in central, residential, commercial or industrial areas; leaf pickup in fall. |
| Milwaukee<br>Wauwatosa<br>West Allis | Weekly sweeping in central business district; biweekly sweeping in residential, commercial or industrial areas; leaf pickup in fall. |
| Brookfield - | Annual sweeping in central, residential, commercial or industrial areas; no leaf pickup in fall. |

*Values for curb length are rough estimates and do not include highways and freeways.
n.a. Not available.

Table III-8. Characteristics of the predominantly single land use drainage areas

| Category | STORET number | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 413616 | 413615 | 683089 | 413011 | 413010 | 413034 | 413614 | 413625 | 463001 | 683090 |
| Area, ha | 47 | 59 | 54 | 543 | 202 | 106 | 135 | 223 | 2,040 | 161 |
| Imperviousness, %: | | | | | | | | | | |
| Total | 89.8 | 44.6 | 50.4 | 34.9 | 53.5 | 73.8 | 18.0 | 22.5 | 4.0 | 24.3 |
| Connected | 89.8 | 43.2 | 44.9 | 28.0 | 32.7 | 32.1 | 6.6 | 0.3 | 1.0 | 0.0 |
| Weighted average slope, % | 1.0 | 5.0 | 2.8 | 4.9 | 3.3 | 3.5 | 3.0 | 3.3 | 3.3 | 4.0 |
| Predominant soil textural class | n.a. | n.a. | Silt loam | Silt loam | n.a. | Silt loam | Silt loam | Silt loam | Silt loam | Silt loam |
| Drainage system | Storm sewered | Storm sewered | Storm sewered | Storm sewered | Storm sewered | Storm sewered | Storm sewered | Natural ditches | Natural ditches | Natural ditches |
| Roof drain connection | To storm sewer | To storm sewer | To storm sewer | To storm sewer | To lawns | To storm sewer | To storm sewer | To lawns | To lawns | To lawns |
| Curb length, km* | 2.4 | 21.4(5.8) | 2.7(0.6) | 104.1 | 49.7 | 10.3(2.9) | 14.6 | 39.3 | 265.4 | 29.6 |
| Curb | None | Concrete | Concrete | Concrete | Concrete | Concrete | None | None | None | None |
| Street pavement | Asphalt | Asphalt | Asphalt | Concrete | Asphalt | Asphalt | Asphalt | Asphalt | Asphalt | Asphalt |
| Pavement condition | Poor | Excellent | Fair | Excellent | Good | Good | Good | Good | Fair | Good |
| Street sweeping** | Monthly | Monthly | None | Biweekly | Biweekly | Biweekly | Annually | None | None | None |
| Catch basin cleaning | Semi-annually | No catch basins | No catch basins | No catch basins | Annually | Annually | Annually | No catch basins | No catch basins | No catch basins |
| Deicing: | | | | | | | | | | |
| Compound | NaCl | CaCl₂/Nacl | n.a. | n.a. | NaCl | NaCl | None | NaCl | NaCl | NaCl |
| Amount,+ metric ton | 45 | 31 | n.a. | n.a. | 3,700 | 4,500 | None | 1,180 | 1,390 | 18 |
| Snow removal | Plowed to side | Plowed to curb | Plowed to side | Plowed to curb | Plowed to curb | Plowed to curb | Plowed to side | Plowed to side | Plowed to side | Plowed to side |
| Traffic,++ vehicle/day | 200 | 150,000 | 11,500 | n.a. | 1,800 | 25,000 | 370 | 2,500 | n.a. | 1,000 |

n.a. Not available.
*The number in parenthesis is the length (total lane km) of non-curbed roadway in the drainage area.
**Street sweeping is performed during the period of April to October.
+Salt application values are estimates from best available data.
++Traffic counts are for workdays.

examples of information not contained in the Land DMS. These values for 1975 were determined using a planimeter on air photographs on which the drainage areas were carefully outlined. The drainage area boundaries were determined from a combination of sources: USGS topographic maps, 0.6 m contour topographic maps and storm sewer plans. The storm sewer plans were required, since in several areas the storm sewers cut across grade. The percent impervious area is determined by hand planimetering all hard surfaces in the drainage area, i.e., roofs, sidewalks, driveways, parking lots and roads. The percent connected impervious area is that portion of the total area that is directly connected to a storm sewer system, i.e., no intervening natural drainage surfaces exist. Table III-A-1 is a complete listing of all land uses in each drainage area for 1975 and Figs. III-A-1 to III-A-10 provide a pictorial description of the 10 drainage areas. The pictorial descriptions and physical data provide a clear description of the characteristics of each monitored drainage area. It should be noted that the drainage areas in Table III-8 and Table III-A-1 are different because the drainage areas in the latter table were determined by computer summation of hectare-sized cells in the Land DMS which only approximate the true configuration of a drainage area.

## Climate

### General climatic conditions

The mid-continental location* of the Watershed, far removed from the moderating effect of the oceans, gives the Watershed a typical continental-type climate characterized primarily by a continuous progression of markedly different seasons and a wide range of annual temperatures. Low winter temperatures are intensified by prevailing frigid northwesterly winds, while summer high temperatures are reinforced by the warm southwesterly winds common during that season.

The Watershed is positioned astride cyclonic storm tracks along which low pressure centers move from the west and southwest. The Watershed also lies in the path of high pressure centers moving in a generally southeasterly direction. Because the Watershed is located at the confluence of major migratory air masses it is affected by a continuously changing pattern of different air masses. Thus, frequent weather changes--particularly in spring and winter when distinct changes normally occur every three or five days--are superimposed on the wide annual range which is characteristic of the area. These temporal weather changes consist of marked variations in temperatures, type and amount of precipitation, relative humidity, wind speed and direction and cloud cover.

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*Unless otherwise indicated, climatic, physiographic and geologic descriptions and data presented herein are based on information extracted from SEWRPC (2).

In addition to these distinct temporal variations in weather, the Watershed--in spite of its relatively small size--exhibits spatial variations in weather due primarily to its proximity to Lake Michigan, particularly during the spring, summer, and fall seasons when the temperature differential between the Lake water and the land air masses tends to be the greatest. During these periods, the presence of the Lake tends to moderate the climate of the eastern border of the Watershed. It is common, for example, for midday summer temperatures in shoreline areas to abruptly drop to a temperature level 12°C lower than inland areas because of cooling lake breezes generated by air rising from the warmer land surfaces. This Lake Michigan temperature influence is, however, generally limited to that portion of the Watershed lying within a few kilometers of the shoreline.

## Temperature

Data for three air temperature observation stations in the Watershed are presented in Table III-9, and their locations are shown in Fig. III-3. The three stations--Germantown (A), Mount Mary College (B) and West Allis (C)--are located along a generally north-south line traversing the length of the Watershed. Coincident periods of record were not used to prepare Table III-9 because of the widely varying periods of record available, some of which are very short, and because of the absence of readily available data summaries. Although non-coincident periods of records were used, the monthly and annual summary data presented in this Section are judged to be sufficiently accurate to portray the spatial and temporal variations in Watershed temperature. These data indicate the temporal variations and in some instances, the spatial variations in temperature and the temperature ranges which may be expected to occur in the Watershed. The temperature data also illustrate how Watershed air temperatures lag approximately one month behind summer and winter solstices during the annual cycle, with the result that July is the warmest month in the Watershed and January the coldest.

Summer air temperatures throughout the Watershed, as reflected by monthly means at the stations for July and August, are in the 20.8°C to 23.1°C range. Average daily maximum temperatures within the Watershed for these two summer months are in the 27.1°C to 28.8°C range, whereas average daily minimum temperatures vary from 13.2°C to 17.0°C. With respect to minimum daily temperatures, the meteorological station network is not sufficient to reflect all the effects of topography. During nighttime hours, cold air, because of its greater density, flows into low-lying areas. Because of this phenomenon, the average daily minimum temperatures in these topographically low areas, particularly during the summer months, will be less than those recorded by the meterological stations. Winter temperatures for the Watershed as measured by monthly means for January and February are in the range of -7.2°C to -4.1°C. Average daily maximum temperatures within the Watershed for these two winter months vary from -3.3°C to -0.2°C, whereas average daily minimum temperatures are in the -13.3°C to -9.4°C range.

Table III-9. Air temperature (°C) characteristics at selected locations in the Menomonee River Watershed

| Month | Location |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Mount Mary College (1948-1975) |  |  | West Allis (1951-1976) |  |  | Germantown (1944-1976) |  |  |
|  | Average daily maximum* | Average daily minimum* | Mean** | Average daily maximum* | Average daily minimum* | Mean** | Average daily maximum* | Average daily minimum* | Mean** |
| January | -2.0 | -11.1 | -6.4 | -2.2 | -10.7 | -6.4 | -2.5 | -12.5 | -7.5 |
| February | -0.1 | -9.1 | -4.5 | 0.1 | -8.2 | -4.0 | -0.4 | -10.5 | -5.5 |
| March | 4.8 | -4.4 | 0.3 | 4.9 | -3.2 | 0.8 | 5.0 | -5.0 | 0.0 |
| April | 13.6 | 2.0 | 7.9 | 13.1 | 3.2 | 8.2 | 13.2 | 1.2 | 7.2 |
| May | 20.3 | 7.3 | 13.9 | 19.8 | 8.5 | 14.1 | 19.6 | 6.2 | 12.9 |
| June | 25.8 | 13.0 | 19.5 | 26.2 | 14.4 | 20.3 | 25.3 | 11.9 | 18.6 |
| July | 28.6 | 16.1 | 22.5 | 28.6 | 17.4 | 23.0 | 27.9 | 14.5 | 21.2 |
| August | 27.8 | 15.5 | 21.8 | 27.6 | 17.2 | 22.4 | 27.4 | 14.1 | 20.7 |
| September | 23.5 | 11.3 | 17.5 | 22.7 | 12.5 | 17.6 | 22.7 | 9.6 | 16.2 |
| October | 17.6 | 5.9 | 11.9 | 16.6 | 6.9 | 11.8 | 16.9 | 4.6 | 10.8 |
| November | 8.3 | 0.8 | 3.9 | 7.8 | -0.3 | 3.8 | 7.6 | -2.1 | 2.7 |
| December | 0.8 | 7.5 | -3.2 | 0.7 | -6.8 | -3.1 | 0.1 | -9.1 | -4.5 |
| Year | 14.1 | 3.2 | 8.7 | 13.8 | 4.3 | 9.1 | 13.6 | 1.9 | 7.7 |

*The monthly average daily maximum temperature and the monthly average daily minimum temperature are obtained by using daily measurements to compile an average for each month in the indicated period of record; the results are then averaged for all months in the period of record.

**The mean monthly temperature is the average of the average daily maximum temperature and daily minimum temperature for each month.

Air temperature data for the three Watershed stations as prescribed in Table III-9 strongly suggest the existence of an urban heat effect (3,4). Large urban complexes have been observed to exhibit higher air temperatures than surrounding rural areas. This temperature differential is greatest during the evening hours of clear days and is partly attributable to the numerous heat sources in an urban environment. Another factor is the more gradual loss of this heat to the atmosphere due to the dense pattern of the urban structures emitting the heat radiating toward each other rather than into the open atmosphere as in rural areas, and due to the presence of atmospheric contaminants which form a barrier to night time radiation from the earth to the atmosphere.

For all months of the year, average daily minimum temperatures for the West Allis station, which is located in a highly urbanized areas, are -16.5°C to -14.8°C higher than average daily minimum temperatures at Germantown, which is located in a rural area. Average daily minimum temperatures recorded at the Mount Mary College observation station, which is located within an urban area containing considerable open space, lie between those observed at West Allis and Germantown. Although Germantown temperatures would be expected to be slightly lower than West Allis temperatures because of the latitudinal effect--the Germantown station is located about 24 km north of the West Allis station--the temperature differential is most pronounced for average minimum daily temperatures, and is too large to be entirely attributable to differences in latitude or topography.

In summary, then, the air temperature data strongly suggest the existence of an urban heat effect at several locations in the Watershed. One consequence of this effect is an increase in precipitation and cloudiness that is convectively produced as a result of air rising from the warmer urban areas.

## Precipitation

Precipitation in the Watershed takes the form of rain, sleet, hail and snow and ranges from gentle showers of trace quantities to destructive thunderstorms, as well as major rainfall-snowmelt events which cause property and crop damage, inundation of poorly-drained areas and stream flooding. Existing sewerage system problems such as overflows from the 27.7 $km^2$ (area tributary to Watershed) combined sewer service area of the City of Milwaukee are the direct result of even small precipitation events. Heavy rainfall events may also require sewage treatment plants to bypass large volumes of partially treated or untreated sewage--in excess of the hydraulic capacity of the plants--into the storm water sewerage system. Such bypassing is necessary because of the excessive quantities of rain, snowmelt and groundwater flowing into the sanitary sewers via manholes, building sewers, building downspouts and foundation drain connections and by infiltration through faulty sewer pipe joints, manhole structures and cracked pipes.

Monthly average total precipitation and snowfall observations with totals for three Watershed stations are presented in Table III-10. The average annual total precipitation in the Watershed, based on a numerical average of data for the three stations is 75.77 cm, expressed as water equivalent where 25 cm of measured snowfall is equivalent to 2.5 cm of water, while the average annual snow and sleet measured as snow and sleet is 106.7 cm.

The precipitation data presented in Table III-10 suggests the existence of an urban effect in the precipitation amounts. The average total precipitation for the Mount Mary College and West Allis stations is approximately 6 cm greater than the Germantown station. Since rainfall-snowmelt events are the driving force in diffuse source pollution (non-point pollution), additional precipitation increases the washoff of pollutants from the urban environment.

It should be noted that the precipitation data presented in Table III-10 are again made up of non-coincident periods of record. Although non-coincident periods of record were used, the monthly and annual summary data presented in the section are judged to be sufficiently accurate to portray the spatial and temporal variations in Watershed precipitation.

## Physiography and Topography

The 355 km$^2$ Menomonee River Watershed is a narrow, irregularly shaped drainage basin, with its major axis oriented approximately north and south (Fig. III-1). Its length--measured between the northernmost and southernmost points--is approximately 37 km, and its maximum width, which occurs in the lower third of the Watershed along a line extending from the Milwaukee Harbor directly west to the Watershed divide, is 19 km. The middle portion of the Watershed is about 8 km wide, while the upper headwater area is approximately 14 km in width.

Watershed physiographic features, or surficial land forms, have been determined largely by the underlying bedrock and the overlying glacial deposits of the Watershed. There is evidence of four major stages of glaciation in southeastern Wisconsin. The last and most influential in terms of present physiography and topography was the Wisconsin stage, which is believed to have ended about 11,000 years ago.

The Niagara cuesta on which the Watershed lies is a gently eastward sloping bedrock surface. The topography in this section is asymmetrical with the eastern border of the Watershed being generally lower--about 46 to 92 m--in elevation than the western border. Glacial deposits overlying the bedrock formations form the irregular surface topography of the Watershed, characterized by rounded hills or groups of hills, ridges, broad undulating plains, and poorly drained wetlands.

Interlobate deposits known as the Kettle Moraine, left between the Green Bay and Lake Michigan lobes, or tongues, of the continental glacier which moved in a generally southerly direction from its point of origin

Table III-10. Precipitation (cm) characteristics at selected locations in the Menomonee River Watershed

| Month | Location |  |  |  |  |  |
|---|---|---|---|---|---|---|
|  | Mount Mary College |  | West Allis |  | Germantown |  |
|  | Average total precipitation (1946-1976) | Average snow and sleet (1961-1976) | Average total precipitation (1951-1976) | Average snow and sleet (1961-1974) | Average total precipitation (1945-1976) | Average snow and sleet (1961-1976) |
| January | 3.91 | 23.9 | 3.51 | 23.1 | 2.87 | 25.9 |
| February | 3.23 | 24.4 | 2.92 | 21.8 | 2.34 | 23.9 |
| March | 5.97 | 20.8 | 5.49 | 20.3 | 4.55 | 29.7 |
| April | 8.31 | 5.8 | 8.33 | 6.6 | 7.04 | 6.6 |
| May | 7.37 | Trace | 7.24 | 0.0 | 7.32 | 0.0 |
| June | 9.14 | 0.0 | 9.47 | 0.0 | 8.76 | 0.0 |
| July | 9.25 | 0.0 | 8.56 | 0.0 | 8.38 | 0.0 |
| August | 7.67 | 0.0 | 7.98 | 0.0 | 8.10 | 0.0 |
| September | 7.21 | Trace | 7.80 | 0.0 | 7.98 | Trace |
| October | 5.82 | Trace | 6.40 | Trace | 5.46 | 0.3 |
| November | 5.08 | 2.5 | 5.59 | 1.8 | 5.11 | 5.6 |
| December | 4.78 | 24.4 | 4.62 | 22.1 | 3.81 | 30.7 |
| Year | 77.74 | 101.8 | 77.91 | 95.8 | 71.72 | 122.7 |

in what is now Canada, lie to the west of the Menomonee River Watershed. The northwest portion of the Watershed lies closest to the Kettle Moraine, and contains rolling ground moraine similar to, but more subdued than, the kettle and kame topography of the Kettle Moraine. This area of rolling ground moraine gives the Watershed its highest elevations and areas of greatest local relief.

Surface elevations within the Watershed range from a high of approximately 342 m above sea level in Washington County, to approximately 177 m above sea level in the Menomonee River industrial valley (Milwaukee), a maximum relief of 165 m. The areas of greatest local relief are located in the northwest portion of the Watershed in Washington County.

Most of the Watershed is covered by gently sloping ground moraine--heterogeneous material deposited beneath the ice--and moraines consisting of material deposited at the forward margins of the ice sheet, and outwash plains formed by the action of flowing glacial meltwater. Glacial land forms are of economic significance because some are prime sources of sand and gravel needed for highway and other construction purposes. Because of their beauty and desirability for homesites, glacial land forms also serve as effective indicators of those rural areas of the Watershed likely to experience concentrated residential development. An example of such an area is the attractive rolling ground moraine area in the northwest portion of the Watershed, which provides an excellent view of the Kettle Moraine to the west.

Topography is important to Watershed planning since it is one of the important factors determining the hydrologic response of a Watershed to rainfall and rainfall-snowmelt events, and since topographic considerations enter into the selection of sites and routes for public utilities and facilities such as sewerage and water supply systems and highways. Some type of large scale mapping is available for about 350 $km^2$, or about 98 percent, of the total Watershed area. Of that total, 145 $km^2$, representing about 42 percent of the Watershed, is covered by large scale topographic mapping prepared using SEWRPC recommended procedures. For the remaining area, other large scale topographic mapping and sanitary and storm sewer maps either with or without street grade elevations are available. More detailed mapping information is available from SEWRPC (1). The above mapping, together with scale aerial photographs available for the entire Watershed, were used extensively during the Watershed.

As already noted, a major subcontinental divide that separates Mississippi River basin drainage from Great Lakes-St. Lawrence River basin drainage forms much of the western boundary of the Menomonee River Watershed. In addition to the physical significance of the subcontinental divide--it established the overall easterly direction of Menomonee River Watershed surface drainage--the subcontinental divide also carries with it certain legal constraints on the diversion of water across the divide. Also of significance are the water quality requirements imposed on the Watershed as a result of its being tributary to Lake Michigan.

The Fox River and Rock River Watersheds lie west of the Menomonee River

Watershed and of the subcontinental divide. On the north and east, the Menomonee River Watershed adjoins the large Milwaukee River Watershed, while the Kinnickinnic River, Oak Creek, and Root River Watersheds lie to the south of the Menomonee River Watershed. Comprehensive watershed plans have been completed and adopted by the SEWRPC for three of the six watersheds contiguous to the Menomonee River Watershed--the Root River, Fox River, and Milwaukee River Watersheds--while in December 1974 the SEWRPC published a prospectus for one of the remaining three contiguous watersheds--the Kinnickinnic River Watershed.

Surface drainage within the Watershed is very diverse with respect to channel shape and slope, the degree of stream sinuosity, and floodland shape and width. The heterogeneous character of the surface drainage system is partly due to the natural effects of recent glaciation superimposed on the bedrock geology, and partly due to the extensive channel modifications evident in the lower Watershed.

## Geology

The geology of the Menomonee River Watershed is a complex system of various layers and ages of rock formations. The type and extent of the various bedrock formations underlying the Watershed were determined primarily by the environments in which the sediments forming the various rock layers were deposited. The surface of this varied system of rock layers was, moreover, deeply eroded prior to being buried by a blanket of glacial deposits consisting of unconsolidated sand, silt, clay, gravel, and boulders. The bedrock formations underlying the Menomonee River Watershed consist of, in ascending order, predominantly crystalline rocks of the Precambrian Era, Cambrian through Devonian Period sedimentary rocks of the Paleozoic Era, and unconsolidated surficial deposits. Only the glacial deposits and the youngest sedimentary rocks are exposed in the Watershed. The subsurface stratigraphy of the Menomonee River Watershed is summarized in Table III-11.

Precambrian crystalline rocks thousands of meters thick formed the basement on which younger rocks were deposited. Little is known of their origin, but in wells within or near the Watershed that reach the Precambrian basement, the rock types include quartzite and granite. The Precambrian rocks were extensively eroded to an uneven surface before the overlying sedimentary formations were deposited. Layered sedimentary rocks overlying the Precambrian rocks consist primarily of sandstone, shale, and dolomite. These rocks were deposited during the Cambrian, Ordovician, Silurian, and Devonian geologic time periods, in seas that covered much of the present North American continent.

The Cambrian rocks in the Watershed are primarily sandstone, but contain some siltstone, dolomite, and shale. The most dominant Cambrian rock units are the two lowermost units, the Mount Simon sandstone which was deposited on the Precambrian surface, and the Eau Claire sandstone. The two units are present throughout the Watershed. The other three Cambrian rock units

Table III-11. Stratigraphy of the Menomonee River Watershed

| Geologic Age | Stratigraphic unit | Thickness range, m | Lithology | Areal extent |
|---|---|---|---|---|
| Holocene | Alluvium and marsh deposits | | Peat, clay, silt, sand and gravel. | Occurs only locally in stream, valleys and marshes. |
| Pleistocene | Glacial deposits | 0-8(?) | Clay, silt, sand and gravel. | Underlies entire watershed except on rock outcrops. |
| Devonian | Dolomite, undifferentiated | 0-11 | Dolomite, thick-bedded, gray. | Recognized only in three wells in the southeastern part of the watershed. |
| Silurian | Dolomite, undifferentiated | 14-136 | Dolomite, dense, thick-bedded, light gray; some beds cherty; some coral reefs. | Underlies entire watershed. |
| Ordovician | Maquoketa Shale, undifferentiated | 31-63 | Shale, dolomitic, gray, with interbedded dolomite. | Underlies entire watershed. |
| | Galena Dolomite, Decorah Formation and Platteville Formation, undifferentiated | 66-101 | Dolomite, light gray to tan. Sandy dolomite or dolomitic sandstone at base. | Underlies entire watershed. |
| | St. Peter Sandstone | 24-78 | Sandstone, medium to fine grained, dolomitic, white to light gray. | Underlies entire watershed. |
| Cambrian | Trempealeau Formation | 0-5 | Sandstone, very fine to medium grained. Dolomite light gray, interbedded with siltstone in lower part. | These units are recognized only in one well in the southwest part of the watershed. |
| | Franconia Sandstone | 0-3(+) | Sandstone, very fine to medium grained, glauconitic. | |
| | Galesville Sandstone | 0-41 | Sandstone, fine to medium grained, light gray. | Recognized only in two wells, in southern part of watershed. |
| | Eau Claire Sandstone | 35-104 | Sandstone, very fine to medium grained. Dolomite and shale. | These units underlie entire watershed. |
| | Mount Simon Sandstone | 78-519+(?) | Sandstone, fine to coarse grained, white or light gray. Some interbedded thin shale. | |
| Precambrian | Undifferentiated | (Thousands of meters) | Crystalline rocks including granite and quartzite. | Underlies entire watershed. |

in the Watershed--the Galesville sandstone, Franconia sandstone, and Trempealeau formation--are younger than the Mount Simon and Eau Claire sandstones, and have been found only locally in the southern portion of the Basin. Most of the Galesville and Franconia sandstones and the Trempealeau formation were probably eroded and thereby removed from the Watershed before deposition of the Ordovician rock units. Cambrian rocks are thickest in the Milwaukee County area, where the combined thickness of the Mount Simon and Eau Claire sandstones is probably in excess of 366 m. Northward into the headwater areas of the Watershed, the thickness of the Cambrian rocks is significantly reduced to about 183 m.

The Ordovician rocks in the Watershed consist of sandstone, dolomite, and shale. The St. Peter sandstone, which was deposited on an erosion surface cut into the underlying Cambrian formations, has a relatively uniform thickness of about 61 m over much of the Watershed except for the northern portions, where it appears to thin to less than 46 m. The Platteville formation, Decorah formation, and Galena dolomite were deposited in succession on top of the St. Peter sandstone, but are not differentiated in the Watershed. The combined thickness of these dolomitic units is generally between 61 and 92 m. Above these is the Maquoketa shale, which has a thickness of about 61 m throughout the Watershed.

The Silurian rocks consisting of undifferentiated dolomite strata overlie the Maquoketa shale. They form the bedrock beneath the glacial deposits in essentially all of the Watershed. The outcrops of Silurian dolomite appeared and were quarried at several localities within the Watershed. Relative to most of the other rock units found in the Watershed, the thickness of the Silurian dolomite exhibits marked spatial variations. Thickness ranges from a minimum of about 31 to 46 m in the southeastern portion of the Watershed and in the Village of Menomonee Falls to a maximum of over 137 m in the City of Mequon. Large local differences in the thickness of the Silurian dolomite are probably due to pre-glacial and glacial erosion. Dolomitic rocks of Devonian age are known to overlie the Silurian dolomite at only three well locations in the southeastern part of the Watershed.

The unconsolidated deposits of boulders, gravel, sand, silt and clay overlie the sedimentary rocks. These were deposited during the Pleistocene age by continental glaciers that covered the Region intermittently between one million and possibly as recently as 5,000 years ago. The deposits can be classified according to their origin into till and stratified drift. Till, a heterogeneous mixture of clay, silt, sand, gravel, and boulders, was deposited from ice without the sorting action of water. Most of the Watershed is overlain by till in the form of either ground moraine or end moraine. Stratified drift consists primarily of sand and gravel that was sorted and deposited as outwash by glacial meltwater. Part of the Village of Germantown in the extreme northwestern portion of the Menomonee River Watershed is overlain with stratified drift. Although end moraine deposits are composed mainly of till, they may locally contain stratified drift in the form of outwash sand and gravel.

Holocene materials consist of alluvium and marsh deposits. They occur only along streams and in marshy areas, and constitute a very small fraction of the unconsolidated deposits covering the Watershed land surface.

Table III-12 summarizes the lithology and water-yielding characteristics of the unconsolidated, deposits of the Pleistocene and Holocene Ages in the Menomonee River Watershed. As indicated in the table, the unconsolidated deposits are lithologically varied and generally yield only small quantities of water to wells.

## Soils

### Soil associations

The nature of the soils in the Menomonee River Watershed is the result of the interaction of parent materials, topography, climate, vegetation and animals, and time. Within each soil, the effects of these soil-forming factors are reflected in the transformation of soil material in place, chemical removal of soil components by leaching or physical removal by wind or water erosion, additions by chemical precipitation or physical deposition and transfer of some soil components from one part of the soil profile to another.

Diversity of soils exist in the Menomonee River Watershed due to spatial variations of soil-forming factors particularly topography and composition of parent materials.

Soil associations indicate the general idea of the soils in a watershed. A soil association is a landscape that has a distinctive proportional pattern of soils. It consists of one or more major soils and at least one minor soil, and is named after the major soils. The soils in one association may occur in another, but in a different pattern.

The five soil associations identified in the Menomonee River Watershed were compiled from the soil survey reports of the four counties comprising the Watershed (5,6,7). The distribution of these soil associations are depicted in Fig. III-4. It is noted from Fig. III-4 that soils appear to be more varied in the northwestern section of the Watershed.

#### Ozaukee-Mequon

*Well-drained to somewhat poorly-drained soils that have a subsoil of silty clay loam and silty clay; formed in thin loess and silty clay loam glacial till; on moraines.*

The soils in this association are in the uplands on silty clay loam glacial till. They are mostly gently sloping and sloping. Somewhat

Table III-12. Lithology and water-yielding characteristics of the unconsolidated deposits of Pleistocene and Holocene Ages in the Menomonee River Watershed

| Unit | General description | Water-yielding characteristics |
|---|---|---|
| Organic deposits | Peat and muck | Generally saturated; not used as a source of water for wells |
| Stream alluvium | Clay, silt, and sand; sorted and stratified | Generally saturated but too thin to be a source of water for wells |
| Buried outwash | Mostly sand and gravel, sorted and stratified, lying within or beneath glacial till | Yield small to moderate quantities of water |
| Ice-contact deposits | Clay, silt, sand, gravel, and boulders; unstratified to stratified and unsorted to sorted | Yield small quantities of water; upper part commonly unsaturated |
| Glacial till | Clay, silt, sand, gravel, and boulders; unsorted and unstratified | Permeability low to very low; not used as a source of water for wells |

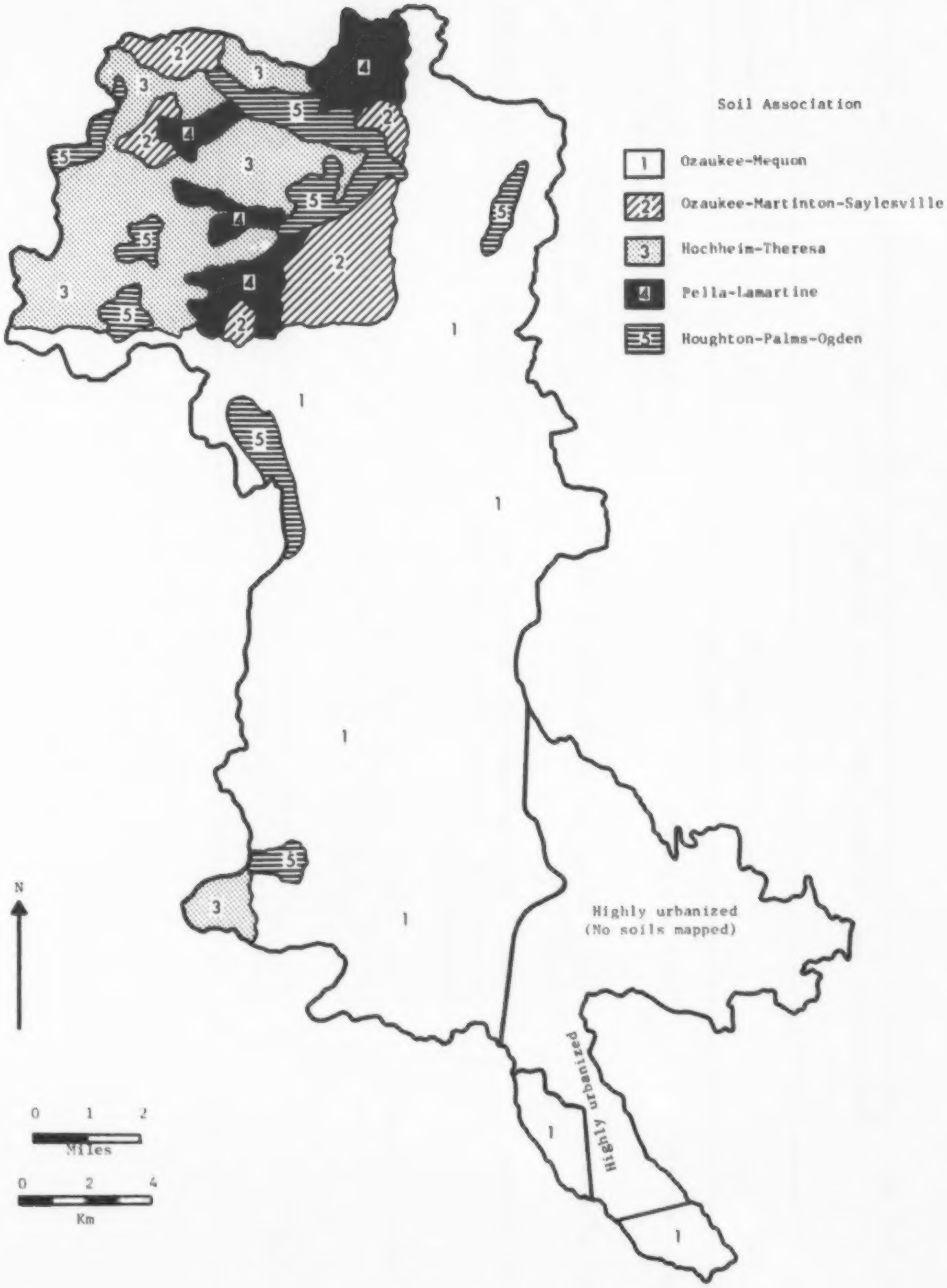
Soil Association
1 Ozaukee-Mequon
2 Ozaukee-Martinton-Saylesville
3 Hochheim-Theresa
4 Pella-Lamartine
5 Houghton-Palms-Ogden
Highly urbanized
(No soils mapped)
Highly urbanized
N
0 1 2
Miles
0 2 4
Km

Fig. III-4. Generalized soil map of the Menomonee River Watershed.

poorly-drained soils are along waterways and in scattered broad drainageways.

The major soils are the Ozaukee and Mequon series. The Ozaukee soils make up about 9,126 ha and Mequon about 4,360 ha. Among the minor soils are Ashkum and Sebewa.

The Ozaukee soils are nearly level to sloping and they occupy ridges and convex side slopes of glacial moraines. They are well-drained to moderately well-drained. The surface layer of these soils is dark grayish-brown silt loam and the subsoil is silty clay loam.

The Mequon soils which are generally gently sloping occur in drainageways and depressions. They have restricted drainage and temporary high water table. Their surface layer is very dark grayish-brown silt loam, their subsoil is silty clay loam to silty clay and mottled.

The minor soils in this association are in depressions and on low flats along major drainageways. They are generally poorly drained.

## Ozaukee-Martinton-Saylesville

*Well-drained and somewhat poorly-drained soils that have a subsoil of silty clay loam to clay; over silty clay loam glacial till or lake-laid silt and clay; on ground moraines and lacustrine basins.*

This association consists of nearly level to steep soils that are underlain by calcareous silty clay loam glacial till and lacustrine silt and clay. The landscape consists of soils that form broad, smooth hills and valleys. The drainage patterns in the association is irregular.

The Ozaukee soils occupy about 1,654 ha in the Watershed; Martinton soils (formerly named Tichigan), 430 ha; and Saylesville soils, 206 ha.

The Ozaukee soils are nearly level to sloping and they occupy ridges and convex side slopes of glacial moraines. They are well-drained to moderately well-drained. The surface layer of these soils is dark grayish-brown silt loam and the subsoil is silty clay loam.

The Saylesville soils are nearly level to gently sloping formed in lacustrine silt and clay. These well-drained soils have a silt loam surface layer and a silt clay loam to clay subsoil.

The Martinton soils, formed in lacustrine silt and clay, are in depressional areas and somewhat poorly-drained. Their surface layer is grayish-brown silt loam and their subsoil is mottled silty clay.

Some of the minor soils in this association are the Mequon and Montgomery (formerly Bono) series. These nearly level and gently sloping soils are in depressions or in drainageways between the gently sloping soils of the broad uplands. The Mequon soils are somewhat poorly drained and the Montgomery soils are poorly drained.

### Hochheim-Theresa

*Well-drained soils that have a subsoil of clay loam and silty clay loam; formed in loess and loam glacial till; on ground moraines.*

This association consists of nearly level to steep soils, mostly on drumlins, that are underlain by calcareous sandy loam to loam glacial till. The major soils of this association are well-drained.

The major soils of this association occupy about 1,989 ha of the Watershed. Hochheim soils make up about 1,055 ha and Theresa about 934 ha.

The Hochheim soils are generally sloping or moderately steep and occur mainly on ground moraines and convex side slopes of drumlins above the Theresa soils. These well-drained soils formed in calcareous loamy glacial till. They have a loam and silt loam surface layer and a clay loam to loam subsoil.

The Theresa soils, which are nearly level to sloping, occur in convex side slopes of uplands, generally below the Hochheim soils. They are underlain by loess or calcareous loamy glacial till and are well-drained. The surface layer of these soils is dark grayish-brown silt loam and the subsoil is mainly clay loam to loam.

The minor soils in the association include the Mayville, Lamartine, Brookston, Pella and Miami series. These soils except the Miami series occur along foot slopes or between sloping to steep soils on hills and ridges and they are somewhat poor to poorly drained.

### Pella-Lamartine

*Somewhat poorly drained and poorly drained soils that have a subsoil of clay loam or silty clay loam; formed in loess and underlying loam to sandy loam glacial till.*

The soils in this association are nearly level to gently sloping underlain by calcareous loam to sandy loam glacial till. They occur on ground moraines. The topography consists mainly of low drainageways and some broad, irregular areas between uplands.

The major soils occupy about 1,202 ha of the Watershed with Pella (formerly Ehler) comprising 929 ha and Lamartine, 273 ha.

The nearly level Pella soils formed in calcareous loamy till occur in low lands. These soils are poorly drained. The surface layer of these soils is black silt loam and the subsoil is gray silty clay loam and silt loam.

The Lamartine soils are nearly level to gently sloping formed in loess over calcareous loamy till. These soils along footslopes of uplands are somewhat poorly drained. They have a surface layer of very dark gray silt loam. Their subsoil is mottled silt loam and silty clay loam.

Among the minor soils of this association are Brookston, Kendall (formerly Clyman) and Palm series. These somewhat poorly drained soils are underlain by loamy glacial till.

### Houghton-Palms-Ogden

*Very poorly drained organic soils along drainageways, in depressions and in old lakebeds.*

This association consists of nearly level, very poorly drained organic soils formed from dead and decaying remains of plants. They occur on lowlands that in most places are along drainageways, in marshy depressions, and in old lakebeds.

The major soils in the association occupy about 1,555 ha of the Watershed. The Houghton soils make up about 782 ha of the Watershed and Palm soils about 497 ha and Ogden soils about 276 ha.

The Houghton soils, which occur in larger organic areas, contain more than 42 inches of muck or mucky peat deposits over sandy to loamy materials. The Palms soils are shallower than the Houghton and are generally in narrow drainageways and depressions or along outer margins of Houghton soils. They are are formed in less than 42 inches of organic deposits over loamy materials. The Ogden soils, found in depressions and in old lakebeds, have black mucky peat underlain by clayey material at a depth of less than 60 inches.

The minor soils in this association are poorly drained and include the Pella, Brookston, Mussey, Sebewa, Muskego, Rollin, and Adrian series.

### Soil texture, slope, permeability and hydrologic group

In the Menomonee River Watershed about 70 soil series and 100 soil types have been identified. The area covered and some properties of the various soil types are listed in Table III-13.

Detailed soils data are available for 29,290 ha, or 83% of the Menomonee River Watershed. The excluded area consists of the heavily urbanized easternmost portion of the Watershed. Detailed descriptions of the soils as well as interpretations of soil characteristics and properties for engineering, agricultural, resource conservation, and urban and rural planning purposes are

**Table III-13. Areal extent and some water management characteristics of the various soil types in the Menomonee River Watershed**

| Soil type | Areal extent* Area, ha | Areal extent* %** | Hydrologic soil group | Depth of A horizon, cm | Permeability of A horizon cm/hr | Available $H_2O$ capacity, cm/cm | Depth to $H_2O$ table, cm | Drainage class |
|---|---|---|---|---|---|---|---|---|
| Silt loams | 23,322 | 88.0 | | | | | | |
| Ozaukee | 10,780 | 40.7 | C | 0-20 | 2.0-6.4 | 0.51 | 90-150 | Well to moderately well |
| Mequon | 4,360 | 16.4 | C | 0-20 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Hochheim | 1,055 | 3.98 | B | 0-23 | 2.0-6.4 | 0.46 | >150 | Well |
| Theresa | 936 | 3.52 | B | 0-23 | 2.0-6.4 | 0.51 | >150 | Well |
| Ehler*** | 929 | 3.51 | D | 0-23 | 6.4-12.7 | 0.61 | 0-30 | Poor |
| Sebewa | 527 | 1.99 | D | 0-38 | 2.0-6.4 | 0.61 | 0-30 | Poor to very poor |
| Knowles | 493 | 1.86 | B | 0-18 | 2.0-6-4 | 0.51 | >150 | Well |
| Matherton | 455 | 1.72 | C | 0-28 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Tichigan*** | 430 | 1.62 | C | 0-28 | 2.0-6.4 | 0.51 | 90-150 | Somewhat poor |
| Mayville | 378 | 1.43 | B | 0-28 | 2.0-6.4 | 0.51 | 90-150 | Moderately well |
| Casco | 281 | 1.06 | B | 0-23 | 2.0-6.4 | 0.51 | >150 | Well |
| Lamartine | 273 | 1.03 | C | 0-30 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Colwood | 256 | 0.97 | D | 0-30 | 2.0-6.4 | 0.66 | 0-30 | Poor to very poor |
| Fox | 228 | 0.86 | B | 0-25 | 2.0-6.4 | 0.51 | >150 | Well |
| Saylesville | 206 | 0.78 | C | 0-23 | 2.0-6.4 | 0.46 | 30-90 | Well to moderately well |
| Pistakee | 188 | 0.71 | C | 0-64 | 2.0-6.4 | 0.56 | 30-90 | Somewhat poor |
| Kibbie | 179 | 0.68 | C | 0-18 | 2.0-6.4 | 0.46 | 30-90 | Somewhat poor |
| Clyman | 167 | 0.63 | C | 0-30 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Westland | 160 | 0.60 | D | 0-30 | 2.0-6.4 | 0.61 | 0-30 | Poor |
| Calamus | 148 | 0.56 | B | 0-25 | 2.0-6.4 | 0.51 | 90-150 | Moderately well |
| Sisson | 147 | 0.55 | B | 0-20 | 2.0-6.4 | 0.56 | >150 | Well |
| Sleeth | 92 | 0.35 | C | 0-30 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Brookston | 85 | 0.32 | D | 0-30 | 2.0-6.4 | 0.61 | 0-30 | Poor |
| Ionia | 72 | 0.27 | B | 0-23 | 2.0-6.4 | 0.51 | 90-150 | Moderately well |
| Dodge | 60 | 0.23 | B | 0-30 | 2.0-6.4 | 0.51 | >150 | Well |
| Fabius | 57 | 0.22 | C | 0-23 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Lorenzo | 35 | 0.13 | B | 0-20 | 2.0-6.4 | 0.51 | >150 | Well |
| Juneau | 31 | 0.12 | C | 0-66 | 2.0-6.4 | 0.51 | 90-150 | Well to moderately well |
| Menno | 31 | 0.12 | C | 0-33 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Thackery | 30 | 0.11 | B | 0-30 | 2.0-6.4 | 0.51 | 90-150 | Moderately well |
| Ockley | 30 | 0.11 | B | 0-33 | 2.0-6.4 | 0.51 | >150 | Well |
| Mosel | 28 | 0.10 | C | 0-33 | 6.4-12.7 | 0.51 | 30-90 | Somewhat poor |
| Lawson | 25 | 0.09 | D | 0-64 | 2.0-6.4 | 0.61 | 30-90 | Somewhat poor |
| Abington | 21 | 0.08 | D | 0-46 | 2.0-6.4 | 0.61 | 0-30 | Very poor |
| Blount | 20 | 0.08 | C | 0-28 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Ashford | 20 | 0.08 | B | 0-28 | 2.0-6.4 | 0.46 | 90-150 | Moderately well |
| Mussey | 18 | 0.07 | D | 0-46 | 2.0-6.4 | 0.61 | 0-30 | Poor to very poor |
| Hebron | 17 | 0.06 | B | 0-23 | 2.0-6.4 | 0.56 | 90-150 | Well to moderately well |
| Morley | 12 | 0.04 | C | 0-20 | 2.0-6.4 | 0.51 | 90-150 | Well to moderately well |
| Aztalan | 12 | 0.04 | C | 0-23 | 2.0-6.4 | 0.56 | 30-90 | Somewhat poor |
| Yahara | 11 | 0.04 | C | 0-25 | 2.0-6.4 | 0.56 | 30-90 | Somewhat poor |
| Navan | 9.4 | 0.04 | D | 0-30 | 2.0-6.4 | 0.56 | 0-30 | Poor to very poor |
| Wallkill | 6.5 | 0.02 | D | 0-81 | 2.0-6.4 | 0.51 | 0-30 | Poor |
| Crosby | 5.6 | 0.02 | C | 0-30 | 2.0-6.4 | 0.46 | 30-90 | Somewhat poor |
| Kane | 4.9 | 0.02 | C | 0-33 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Wauconda | 3.8 | 0.01 | C | 0-25 | 2.0-6.4 | 0.56 | 30-90 | Somewhat poor |
| Miami | 3.2 | 0.01 | B | 0-28 | 2.0-6.4 | 0.61 | >150 | Well |
| Warsaw | 3.1 | 0.01 | B | 0-30 | 2.0-6.4 | 0.51 | >150 | Well |
| Keowns | 2.2 | <0.01 | D | 0-30 | 2.0-6.4 | 0.61 | 0-30 | Poor |
| Ashkum-Beecher | 1.1 | <0.01 | C-D | 0-33 | 2.0-6.4 | 0.51 | 0-90 | Somewhat poor to poor |
| Dorchester | 0.9 | <0.01 | B | 0-51 | 2.0-6.4 | 0.51 | 90-150 | Well to moderately well |
| Varna | 0.3 | <0.01 | B | 0-33 | 2.0-6.4 | 0.56 | 90-150 | Well to moderately well |
| Tippecanoe | 0.2 | <0.01 | B | 0-30 | 2.0-6.4 | 0.61 | 90-150 | Moderately well |
| Loams | 408 | 1.54 | | | | | | |
| Matherton | 103 | 0.39 | C | 0-33 | 2.0-6.4 | 0.41 | 30-90 | Somewhat poor |
| Fox | 59 | 0.22 | B | 0-23 | 2.0-6.4 | 0.41 | >150 | Well |
| Casco | 52 | 0.20 | B | 0-23 | 2.0-6.4 | 0.41 | >150 | Well |
| Hochheim | 46 | 0.17 | B | 0-23 | 2.0-6.4 | 0.41 | >150 | Well |
| Fabius | 45 | 0.17 | C | 0-23 | 2.0-6.4 | 0.41 | 30-90 | Somewhat poor |
| Casco-Rodman | 23 | 0.09 | A-B | 0-23 | 2.0->25.4 | 0.05-0.41 | >150 | Well to excessive |
| Hochheim-Sisson-Casco | 22 | 0.08 | B | 0-23 | 2.0-6.4 | 0.41-0.51 | >150 | Well |
| Aztalan | 15 | 0.06 | C | 0-23 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Sebewa | 10 | 0.04 | D | 0-38 | 2.0-6.4 | 0.51 | 0-30 | Poor to very poor |
| Knowles | 5.3 | 0.02 | B | 0-23 | 2.0-6.4 | 0.41 | >150 | Well |
| Ockley | 5.1 | 0.02 | B | 0-33 | 2.0-6.4 | 0.51 | >150 | Well |
| Hochheim-Hennepin | 5.1 | 0.02 | B | 0-23 | 2.0-6.4 | 0.41 | >150 | Well to excessive |
| Hochheim-Theresa | 4.9 | 0.02 | B | 0-23 | 2.0-6.4 | 0.41-0.51 | >150 | Well |
| Hebron | 3.9 | 0.01 | B | 0-23 | 2.0-6.4 | 0.41 | 90-150 | Well to moderately well |
| Mussey | 3.1 | 0.01 | D | 0-46 | 2.0-6.4 | 0.51 | 0-30 | Poor to very poor |
| Rodman | 2.3 | <0.01 | A | 0-20 | >25.4 | 0.05 | >150 | Excessive |
| Ionia | 1.8 | <0.01 | B | 0-25 | 2.0-6.4 | 0.41 | 90-150 | Moderately well |
| Dousman | 1.6 | <0.01 | C | 0-33 | 2.0-6.4 | 0.41 | 30-90 | Somewhat poor |
| Sisson | 0.7 | <0.01 | B | 0-20 | 2.0-6.4 | 0.51 | >150 | Well |
| Yahara | 0.5 | <0.01 | C | 0-25 | 2.0-6.4 | 0.56 | 30-90 | Somewhat poor |
| Muck or mucky peat | 1,587 | 5.99 | | | | | | |
| Houghton | 782 | 2.95 | D | 0->152 | 6.4-12.7 | 0.51 | 0-30 | Very poor |
| Palms | 497 | 1.88 | D | 0-76 | 6.4-12.7 | >0.51 | 0-30 | Very poor |
| Ogden | 276 | 1.04 | D | 0-66 | 6.4-12.7 | >0.51 | 0-30 | Very poor |
| Rollin | 19 | 0.07 | D | 0-96 | 6.4-12.7 | >0.51 | 0-30 | Poor |
| Adrian | 6.6 | 0.02 | D | 0-66 | 6.4-12.7 | >0.51 | 0-30 | Poor |
| Muskego | 6.0 | 0.02 | D | 0-66 | 6.4-12.7 | >0.51 | 0-30 | Poor |
| Sandy loams | 13 | 0.05 | | | | | | |
| Fox | 6.0 | 0.02 | B | 0-25 | 6.4-12.7 | 0.30 | >150 | Well |
| Wea | 4.3 | 0.02 | B | 0-33 | 6.4-12.7 | 0.41 | >150 | Well |
| Lapeer | 1.1 | <0.01 | B | 0-30 | 6.4-12.7 | 0.30 | >150 | Well |
| Parr | 0.6 | <0.01 | B | 0-28 | 6.4-12.7 | 0.41 | >150 | Well |
| Yahara | 0.4 | <0.01 | C | 0-25 | 2.0-6.4 | 0.56 | 30-90 | Somewhat poor |
| Colwood | 0.3 | <0.01 | D | 0-30 | 2.0-6.4 | 0.51 | 0-30 | Poor to very poor |
| Wauconda | 0.3 | <0.01 | C | 0-23 | 2.0-6.4 | 0.51 | 30-90 | Somewhat poor |
| Loamy sands | 7.2 | 0.03 | | | | | | |
| Hackett | 3.6 | 0.01 | A | 0-36 | 12.7-25.4 | 0.18 | >150 | Somewhat excessive |
| Tustin | 3.1 | 0.01 | B | 0-25 | 12.7-25.4 | 0.20 | >150 | Excessive |
| Granby | 0.4 | <0.01 | D | 0-30 | 12.7-25.4 | 0.20 | 0-30 | Poor |
| Tedrow | 0.1 | <0.01 | A | 0-23 | 12.7-25.4 | 0.20 | 30-90 | Somewhat poor |
| Silty clay loams | 1,155 | 4.36 | | | | | | |
| Ashkum | 684 | 2.58 | D | 0-33 | 2.0-6.4 | 0.51 | 0-30 | Poor |
| Bono*** | 471 | 1.78 | D | 0-46 | 0.5-2.0 | 0.51 | 0-30 | Very poor |

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*Total area of the watershed is 35,271 ha of which 26,493 ha (75%) were mapped by soil types. The difference constitutes of the following: alluvial lands = 205 ha; marsh = 3.9 ha; filled areas = 2,342 ha, quarry and gravel pit = 140 ha; dump = 68 ha; water, pond and lake = 39 ha; and highly urbanized area = 5,981 ha.

**Based on 26,493 ha mapped as soil types.

***Present names of the following soils are: Ehler = Pella; Tichigan = Mertinton; Bono = Montgomery.

found in the planning report prepared by SEWRPC (8). Updated and correlated information is given in the soil survey reports for the counties of Ozaukee (5), Washington (6) and Milwaukee and Waukesha (7).

Soils data in the Watershed such as soil types, area, slope, permeability, hydrologic soil groups and other properties have been incorporated in the Land DMS. Utilizing this system soils information can be retrieved and displayed in tabular or graphical form.

Groupings were made according to textural class, slope, permeability of the A-horizon, and hydrologic soil groups. Table III-14 summarizes the areas under each category of textural class, slope, permeability and hydrologic soil group for the entire Watershed. These properties are deemed the most important ones influencing the potential movement of soils in the Watershed. Distributions of these properties in smaller areas, i.e., in 48 subwatersheds of the Watershed, are discussed in Volume 2, Part IV.

The textural class that predominates in the Watershed is silt loam (Tables III-13 and III-14). Silt loams are well-distributed throughout the Watershed with Ozaukee silt loam being the major soil type. This textural class occupies 23,322 ha or 88% of the 26,493 ha mapped as soil types. The organic soils--mucks or mucky peats (6.0%), and the fine-textured soils--silty clay loams (4.4%) occupy moderate areas. Only small scattered areas of coarse textured soils, sandy loams and loamy sands, are found in the Watershed.

Slope is one soil characteristic that has a strong influence on the erosion of soil particles on the land surface. Soil slope varies from a low of 0 to 2% to a high of 30 to 45%. It can be seen from Table III-14 that most of the soils in the Watershed are nearly level to gently sloping, i.e., in the 0 to 2% and 2 to 6% slope ranges corresponding to 34 and 55%, respectively, of the area that was mapped as soil types. Sloping areas (6 to 12% slope range) represent about 10% of the mapped area while steep areas (> 12% slopes) comprise only a small percentage. Although high slope areas represent only a small portion of the Watershed they may present a serious erosion hazard.

Permeability reflects the rate of water movement through a saturated soil. Generally, fine textured soils are less permeable than coarse textured soils. Permeability of the A-horizon varies from a low of 0.5 to 2.0 cm/hr to a high of > 25.4 cm/hr (Table III-14). Soils with low permeability, i.e., 2.0 to 6.4 cm/hr are dominant, occupying about 88% of the total area mapped. Soils with a very low permeability (0.5 to 2.0 cm/hr) exist in about 2% of the area and those with moderate to high permeability (> 6.4 cm/hr), about 10%.

The soils of the Menomonee River Watershed have been classified into four hydrologic soil groups designated as A, B, C, and D, based upon those soil properties affecting runoff. Hydrologic soil groups reflect the ability of soils to restrain runoff from a heavy storm after they have been thoroughly wetted.

Group A soils are mainly sandy or gravelly. They exhibit very low

Table III-14. Summary of the areal (ha) extent of soil textural class, slope, permeability of A horizon and hydrologic group in the Menomonee River Watershed

| | Textural class | | | | | | |
|---|---|---|---|---|---|---|---|
| Soil property | Silt loam | Loam | Sandy loam | Loamy sand | Silty clay loam | Muck/mucky peat | Total* |
| Slope, % | | | | | | | |
| 0-2 | 6,004 | 383 | 0.8 | 3.1 | 1,119 | 1,535 | 9,045 |
| 2-6 | 14,393 | 136 | 8.5 | 4.0 | 27 | 56 | 14,625 |
| 6-12 | 2,561 | 33 | 3.4 | 0.1 | 8.6 | 0 | 2,606 |
| 12-20 | 335 | 45 | 0 | 0 | 0 | 0 | 380 |
| 20-30 | 26 | 17 | 0 | 0 | 0 | 0 | 43 |
| 30-45 | 3.4 | 0 | 0 | 0 | 0 | 0 | 3 |
| Total | 23,322 | 614 | 13 | 7.2 | 1,155 | 1,591 | 26,702 |
| Permeability, cm/hr | | | | | | | |
| 0.5- 2.0 | 0 | 0 | 0 | 0 | 471 | 0 | 471 |
| 2.0- 6.4 | 22,365 | 384 | 1.0 | 0 | 684 | 0 | 23,434 |
| 6.4-12.7 | 957 | 205** | 12 | 0 | 0 | 1,591+ | 2,765 |
| 12.7-25.4 | 0 | 0 | 0 | 7.2 | 0 | 0 | 7 |
| >25.4 | 0 | 25 | 0 | 0 | 0 | 0 | 25 |
| Total | 23,322 | 614 | 13 | 7.2 | 1,155 | 1,591 | 26,702 |
| Hydrologic group | | | | | | | |
| A | 0 | 2 | 0 | 3.7 | 0 | 0 | 6 |
| B | 3,936 | 229 | 12 | 3.1 | 0 | 0 | 4,180 |
| C | 17,346 | 165 | 0.7 | 0 | 0 | 0 | 17,512 |
| D | 2,040 | 218** | 0.3 | 0.4 | 1,155 | 1,591+ | 5,004 |
| Total | 23,322 | 614 | 13 | 7.2 | 1,155 | 1,591 | 26,702 |

*Excludes areas of filled or made land (sand - 15 ha, loam - 824 ha, clay - 1,503 hr), pond and lake (38 ha), quarry and gravel pit (140 ha) and dump (68 ha).

**Includes alluvial lands (205 ha).

+Includes marsh (3.9 ha).

runoff potential because of high infiltration capacity, high permeability, and good internal drainage.

Group B soils have moderately fine to moderately coarse textures which permit moderate amounts of runoff due to moderate infiltration rate, moderate permeability, and moderately good internal drainage.

Group C soils are medium to fine textured soils. Potential for runoff from these soils is large because of slow infiltration capacity, low permeability and poor internal drainage.

Group D soils consist mainly of 1. clay soils with high shrink-swell potential, 2. soils with high permanent water table, 3. soils with claypan or clay layer at or near the surface, and 4. shallow soils with nearly impervious substrata. These soils have high runoff potential because of very slow infiltration rate, low permeability and very poor internal drainage.

Hydrologic soil Group C is dominant in the Watershed (Table III-14). This hydrologic soil group covers about 66% of the portion of the Watershed from which detailed soils data are available. Only a negligible portion of the Watershed is occuped by Group A soils while Groups B and D soils exist in 16 and 19%, respectively, of the total area mapped. Based on this classification the majority of soils in the Watershed have high runoff potential.

## Surface Water Storage Area

Natural surface water storage areas in a watershed serve to modify runoff or rainfall-snowmelt events primarily by decreasing peak discharges and by diminishing the volume of direct runoff as a result of increased infiltration. Natural surface storage areas are generally divided into lakes, wetlands and floodland areas.

No major lake, i.e., 20 ha or more, lies in the Menomonee River Watershed. Water areas, including 14 minor lakes and ponds, comprise only 38 ha. Wetlands consisting of swamps and marshes are located mainly in the headwater portions of the Watershed or along the central western edge. These comprise 1,070 ha or 3% of the Watershed area.

The third type of surface water storage area consists of the floodlands generally associated with streams and water courses. Because of the absence of major lakes and the small areas of remaining wetlands, floodlands constitute the main natural surface water storage areas with the potential for reducing peak discharges of runoff (1). Floodlands are an integral part of the stream system of a watershed and, as such, are regularly inundated by waters. During inundation the floodlands, in effect, store and retard direct runoff, thereby decreasing downstream flood discharges.

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# APPENDIX A. LAND USE AND LANDSCAPE CHARACTERISTICS AT THE PREDOMINANTLY SINGLE LAND USE MONITORING SITES

Table III-A-1. Land use type and area and percent of each use in the predominantly single land use monitoring sites for 1975

| 3 digit SEWRPC code | Land use type | Area, ha | % |
|---|---|---|---|
| | STORET no. 413616 Allis Chalmers | | |
| 111 | Residential single family nonfarm lot under 2 ha | .15 | .31 |
| 210 | Retail sales and service | .11 | .23 |
| 310 | Industrial manufacturing | 38.04 | 77.66 |
| 380 | Industrial storage | 6.82 | 13.92 |
| 418 | Land access and collector streets | .74 | 1.52 |
| 430 | Off street parking | 1.57 | 3.21 |
| 441 | Railroad right of way | 1.55 | 3.16 |
| | Total | 48.98 | 100.01 |
| | STORET no. 413615 Stadium Interchange | | |
| 111 | Residential single family nonfarm lot under 2 ha | 10.47 | 16.26 |
| 120 | Residential two family | .41 | .63 |
| 141 | Residential multi-family low rise | .37 | .58 |
| 199 | Residential land under development | .11 | .18 |
| 210 | Retail sales and service | .45 | .69 |
| 411 | Freeway | 16.86 | 26.19 |
| 414 | Standard arterial street and expressway | 1.30 | 2.02 |
| 418 | Land access and collector streets | 7.43 | 11.55 |
| 430 | Off street parking | 7.84 | 12.18 |
| 441 | Railroad right of way | .36 | .57 |
| 510 | Communication and utilities | .44 | .68 |
| 612 | Region administrative, safety, assembly | .22 | .35 |
| 682 | Regional cemeteries | 15.77 | 24.50 |
| 731 | Rec. public land related rec. area | 2.17 | 3.36 |
| 921 | Unused urban land | .19 | .29 |
| | | 64.39 | 100.03 |
| | STORET no. 683089 Brookfield Square | | |
| 111 | Residential single family nonfarm lot under 2 ha | 5.00 | 8.25 |
| 210 | Retail sales and service | 19.66 | 32.47 |
| 414 | Standard arterial street and expressway | 1.63 | 2.70 |
| 418 | Land access and collector streets | 1.33 | 2.19 |
| 430 | Off street parking | 17.07 | 28.18 |
| 815 | Ag. pasture | 3.81 | 6.29 |
| 921 | Unused urban land | 8.85 | 14.62 |
| 922 | Unused rural land | 3.21 | 5.29 |
| | | 60.56 | 99.99 |
| | STORET no. 413614 Timmerman Airport | | |
| 111 | Residential single family nonfarm lot under 2 ha | 1.21 | .85 |
| 141 | Residential multi-family low rise | .30 | .21 |
| 210 | Retail sales and service | .48 | .34 |
| 310 | Industrial manufacturing | .11 | .08 |
| 380 | Industrial storage | .25 | .18 |
| 414 | Standard arterial street and expressway | 4.44 | 3.13 |
| 418 | Land access and collector streets | .67 | .47 |
| 430 | Off street parking | .59 | .42 |
| 463 | Air field | 126.82 | 89.27 |
| 465 | Air terminal and hangers | 6.75 | 4.75 |
| 921 | Unused urban land | .44 | .31 |
| | | 142.06 | 100.01 |
| | STORET no. 413011 Noyes Creek | | |
| 111 | Residential single family nonfarm lot under 2 ha | 159.02 | 28.74 |
| 113 | Residential single family assoc. with farm bldg. | .19 | .03 |
| 120 | Residential two family | 7.70 | 1.39 |
| 141 | Residential multi-family low rise | 18.16 | 3.28 |
| 142 | Residential multi-family high rise | 2.55 | .46 |
| 199 | Residential land under development | 15.20 | 2.75 |
| 210 | Retail sales and service | 13.07 | 2.36 |
| 310 | Industrial manufacturing | 10.23 | 1.85 |
| 340 | Industrial wholesale | 2.65 | .48 |
| 380 | Industrial storage | 5.79 | 1.05 |
| 411 | Freeway | 8.89 | 1.61 |
| 414 | Standard arterial street and expressway | 30.97 | 5.60 |
| 418 | Land access and collector streets | 69.38 | 12.54 |
| 430 | Off street parking | 20.54 | 3.71 |
| 441 | Railroad right of way | 3.59 | .65 |
| 510 | Communication and utilities | 37.94 | 6.86 |
| 611 | Local administrative, safety, assembly | 3.56 | .64 |
| 641 | Local educational | 16.38 | 2.96 |
| 661 | Local health-clinics | .15 | .03 |
| 662 | Regional health | 3.24 | .59 |
| 731 | Rec. public land related rec. area | 28.04 | 5.07 |
| 732 | Rec. private land related rec. area | 18.66 | 3.37 |
| 813 | Ag. vegetable crops | 1.39 | .25 |
| 815 | Ag. pasture | 5.56 | 1.01 |
| 820 | Ag. orchard and nurseries | 2.42 | .44 |
| 871 | Ag. farm bldg. no assoc. animal husb. | .81 | .15 |
| 910 | General wetlands | .41 | .07 |
| 921 | Unused urban land | 50.05 | 9.05 |
| 922 | Unused rural land | .19 | .03 |
| 930 | Land fill and dumps | 14.56 | 2.63 |
| 950 | Lake, rivers, streams, canals | 2.04 | .37 |
| | | 553.33 | 100.02 |

Table III-A-1 (continued)

| 3 digit SEWRPC code | Land use type | Area, ha | % |
|---|---|---|---|
| | STORET no. 413310 Schoonmaker Creek | | |
| 111 | Residential single family nonfarm lot under 2 ha | 96.84 | 54.31 |
| 120 | Residential two family | 21.36 | 11.98 |
| 141 | Residential multi-family low rise | .45 | .25 |
| 199 | Residential land under development | 2.54 | 1.42 |
| 210 | Retail sales and service | 5.59 | 3.14 |
| 418 | Land access and collector streets | 40.28 | 22.59 |
| 430 | Off street parking | 2.31 | 1.30 |
| 611 | Local administrative, safety, assembly | .54 | .30 |
| 612 | Regional administrative, safety, assembly | .22 | .12 |
| 641 | Local educational | 1.71 | .96 |
| 662 | Regional health | 2.91 | 1.63 |
| 681 | Local cemetaries | 1.97 | 1.11 |
| 731 | Rec. public land related rec. area | 1.61 | .90 |
| | | 178.33 | 100.01 |
| | STORET no. 413034 Wauwatosa | | |
| 111 | Residential single family nonfarm lot under 2 ha | 7.72 | 7.03 |
| 199 | Residential land under development | .36 | .33 |
| 210 | Retail sales and service | 10.05 | 9.15 |
| 310 | Industrial manufacturing | 24.51 | 22.30 |
| 340 | Industrial wholesale | 1.87 | 1.70 |
| 380 | Industrial storage | 2.43 | 2.21 |
| 414 | Standard arterial street and expressway | 4.06 | 3.69 |
| 418 | Land access and collector streets | 4.46 | 4.06 |
| 426 | Truck terminal | 7.76 | 7.06 |
| 430 | Off street parking | 30.32 | 27.60 |
| 441 | Railroad right of way | 1.06 | .96 |
| 510 | Communication and utilities | 1.16 | 1.06 |
| 921 | Unused urban land | 14.12 | 12.85 |
| | | 109.88 | 100.00 |
| | STORET no. 413625 New Berlin | | |
| 111 | Residential single family nonfarm lot under 2 ha | 126.53 | 56.77 |
| 141 | Residential multi-family low rise | 1.50 | .67 |
| 199 | Residential land under development | 5.69 | 2.55 |
| 210 | Retail sales and service | 3.45 | 1.55 |
| 340 | Industrial wholesale | .07 | .03 |
| 380 | Industrial storage | .06 | .03 |
| 414 | Standard arterial street and expressway | 3.01 | 1.35 |
| 418 | Land access and collector streets | 21.80 | 9.78 |
| 430 | Off street parking | 2.84 | 1.27 |
| 611 | Local administrative, safety, assembly | .66 | .30 |
| 682 | Regional cemetaries | 24.29 | 10.90 |
| 732 | Rec. private land related rec. area | 1.38 | .62 |
| 815 | Ag. pasture | 24.49 | 10.99 |
| 820 | Ag. orchard and nurseries | 1.47 | .66 |
| 921 | Unused urban land | 4.53 | 2.03 |
| 922 | Unused rural land | 1.10 | .50 |
| | | 222.87 | 100.00 |

| 3 digit SEWRPC code | Land use type | Area, ha | % |
|---|---|---|---|
| | STORET no. 683090 Elm Grove | | |
| 111 | Residential single family nonfarm lot under 2 ha | 130.66 | 78.99 |
| 112 | Residential single family nonfarm lot over 2 ha | .04 | .02 |
| 199 | Residential land under development | 5.71 | 3.45 |
| 210 | Retail sales and service | .41 | .25 |
| 414 | Standard arterial street and expressway | .59 | .35 |
| 418 | Land access and collector streets | 16.26 | 9.83 |
| 430 | Off street parking | 2.27 | 1.37 |
| 611 | Local administrative, safety, assembly | .59 | .35 |
| 641 | Local educational | 1.10 | .66 |
| 661 | Local health-clinics | .47 | .29 |
| 820 | Ag. orchard and nurseries | 1.21 | .73 |
| 921 | Unused urban land | 3.00 | 1.82 |
| 943 | Woodlands on res. lots w/struct. 1.2-2.0 ha | .55 | .33 |
| 944 | Woodland on res. lot w/ struct. over 2 ha | 2.59 | 1.57 |
| | | 165.45 | 100.01 |
| | STORET no. 463001 Donges Bay | | |
| 111 | Residential single family nonfarm lot under 2 ha | 146.13 | 6.81 |
| 112 | Residential single family nonfarm lot over 2 ha | .27 | .01 |
| 113 | Residential singl family assoc. with farm bldg. | 12.71 | .59 |
| 120 | Residential two family | 3.08 | .14 |
| 141 | Residential multi-family low rise | .84 | .04 |
| 199 | Residential land under development | 34.42 | 1.60 |
| 210 | Retail sales and service | 1.18 | .06 |
| 380 | Industrial storage | .39 | .02 |
| 414 | Standard arterial street and expressway | 20.34 | .95 |
| 418 | Land access and collector streets | 17.56 | .82 |
| 426 | Truck terminal | .51 | .02 |
| 430 | Off street parking | 1.05 | .05 |
| 510 | Communication and utilities | 15.14 | .71 |
| 611 | Local administrative, safety, assembly | .51 | .02 |
| 641 | Local educational | 2.42 | .11 |
| 681 | Local cemetaries | 1.01 | .05 |
| 682 | Regional cemetaries | 24.01 | 1.12 |
| 781 | Rec. public water related rec. area | .34 | .02 |
| 811 | Ag. row crops | 720.30 | 33.58 |
| 812 | Ag. grain crops | 170.48 | 7.95 |
| 813 | Ag. vegetable crops | 218.12 | 10.17 |
| 814 | Ag. hay | 308.35 | 14.38 |
| 815 | Ag. pasture | 105.79 | 4.93 |
| 820 | Ag. orchard and nurseries | 28.19 | 1.31 |
| 871 | Ag. farm bldg. no assoc. animal husb. | 20.46 | .95 |
| 873 | Ag. farm bldg. assoc. with dairy cattle | 11.87 | .55 |
| 877 | Ag. farm bldg. assoc. with hogs | .39 | .02 |
| 910 | General wetlands | 48.61 | 2.27 |
| 921 | Unused urban land | 1.32 | .06 |
| 922 | Unused rural land | 33.31 | 1.55 |
| 940 | General woodlands | 181.92 | 8.48 |
| 950 | Lake, rivers, streams, canals | 13.98 | .65 |
| | | 2,145.00 | 99.99 |

Fig. III-A-1. Allis Chalmers Corporation. STORET number 413616

Stormwater from this drainage area is conveyed via an underground stormwater sewerage system to the plant's clarifier pond. The main storm sewer, leading to the clarifier pond, contains an overflow weir which directs a portion of the stormwater flow to the outlet system where the monitoring station is located. Stormwater flow from the clarifier pond will depend on the volume of the flow into the pond and the level of the pond. Almost all storms result in flow to the outlet storm sewerage system since the pond is maintained at its maximum level. Stormwater enters the stormwater sewerage system of the City of West Allis which drains into the Menomonee River. Heavy industrial activity predominates in this drainage area. The plant buildings were constructed in the early 1900's.

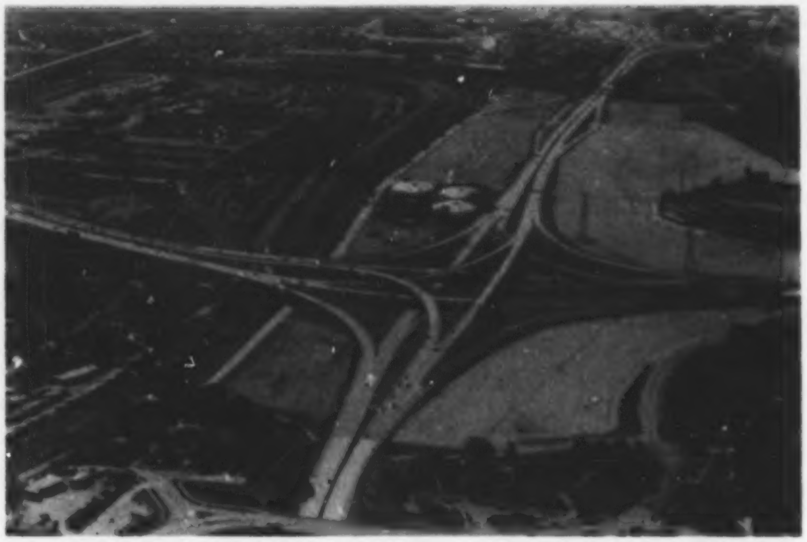

Fig. III-A-2. Stadium Interchange, I-94. STORET number 413615

Stormwater from this drainage area is conveyed via an extensive underground stormwater sewerage system directly to the Menomonee River which can be seen in the upper left portion of the photograph. The drainage area includes the interchange and approach roads, and in addition, a parking lot and a portion of a single family residential area and cemetery in the lower right portion of the photograph. The monitoring station is located in the outlet stormwater sewer 61 m above the sewer's outfall to the Menomonee River.

Fig. III-A-3. Brookfield Square Shopping Center. STORET number 683089

Stormwater from the shopping mall, an office building and their parking lots drains directly to an underground stormwater sewerage system. In addition, a small residential area, an outdoor theater and unused land drains via natural drainage ditches to the shopping mall's stormwater sewerage system. Most structures in the drainage area were constructed in the last 15 years. The only exception being a 7800 $m^2$ expansion of the mall and parking area during mid-April to July of 1977. The monitoring station is located in the outlet stormwater sewer which drains to Underwood Creek, a major tributary to the Menomonee River.

Fig. III-A-4. Noyes Creek. STORET number 413011

Stormwater from this drainage area is conveyed via an underground storm sewerage system to Noyes Creek which is an open grassed channel. The area is predominantly medium density residential with two large commercial complexes and a major expressway traversing the area. Development started in the area during mid-1960's. Prior to and throughout the study period, residential construction continued on approximately 8 ha of land adjoining the Creek. In addition, approximately 1.2 km of roadway were constructed in the summer of 1977, and in the late summer construction began on a 2 ha site for an electrical power transfer station. Construction activity was always preceded by the construction of the stormwater sewerage network. No sediment control procedures were employed at any of the construction sites. The monitoring station is located on Noyes Creek approximately 400 m above the Creek's confluence with the Little Menomonee River.

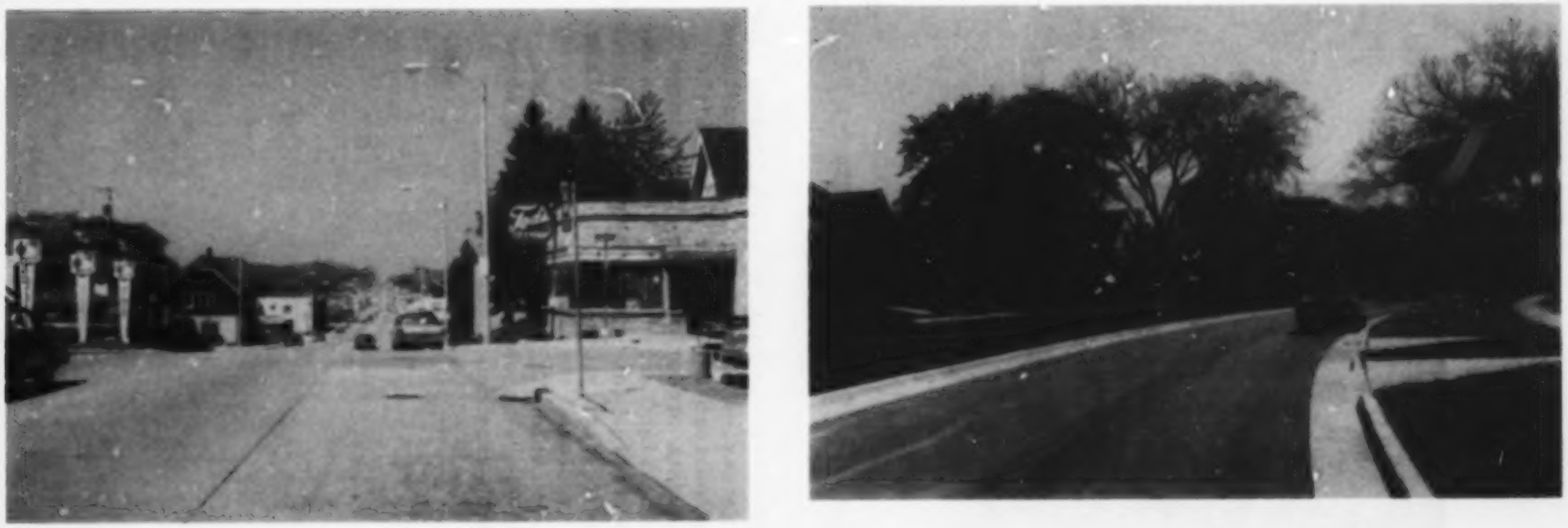

Fig. III-A-5. Schoonmaker Creek. STORET number 413010

Stormwater from this drainage area is conveyed via an underground storm sewerage system to Schoonmaker Creek which is an open channel with stone walls for banks. The upper 75% of the drainage area is medium density residential with a small commercial district along North Avenue (left photograph). It is sharply delineated from the lower portion of the drainage area which is low to medium density residential (right photograph). Both areas were established in early 1940 and are well treed with Dutch Elms even though Dutch Elm disease is present in the area. Autumn leaf pickup is offered weekly. During May to July of 1977 approximately 2 km of streets were removed and rebuilt from the base up. The monitoring station is located on Schoonmaker Creek approximately 975 m above the Creek's confluence with the Menomonee River.

Fig. III-A-6. City of Wauwatosa. STORET number 413034

The drainage area is divided approximately in half by 124th Street. The area west of 124th Street is drained by a series of natural drainage ditches which empty into the fully storm-sewered eastern half of the area. Light industry, wholesale and retail establishments predominate in the drainage area. The Briggs and Stratton Corporation plant and parking lot has its own drainage system (23% of the area) which empties into an open cooling reservoir. Any excess stormwater is passed into the regular storm sewerage system from the reservoir, otherwise the water is circulated through the plant and reservoir as a closed system. The monitoring station is located in the outlet storm-water sewer that services the drainage area approximately 850 m above the point where the sewer drains into the Menomonee River.

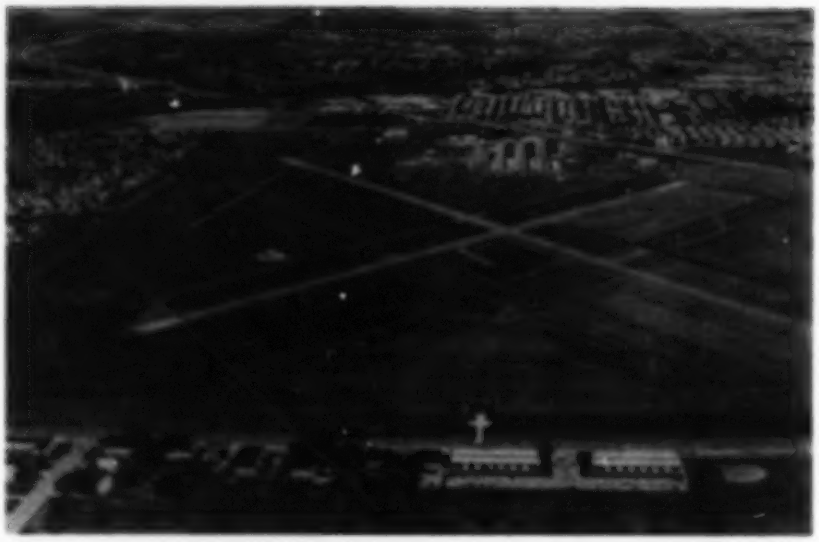

Fig. III-A-7. Timmerman Airport. STORET number 413614

Stormwater from this drainage area is conveyed via an extensive underground stormwater sewerage system. The hangar areas, roof drains, parking lots and turnabout areas are directly connected to storm sewers. The runways are not storm sewered, but there are stormwater inlets located nearby in the grassed areas, as well as intermittently throughout the grassed field. The airport services approximately 135,000 small propeller and turbo-propeller planes each year. The main airport structures were built 20 to 50 years ago. The monitoring station is located in the outlet stormwater sewer and ultimately drains to the Little Menomonee River.

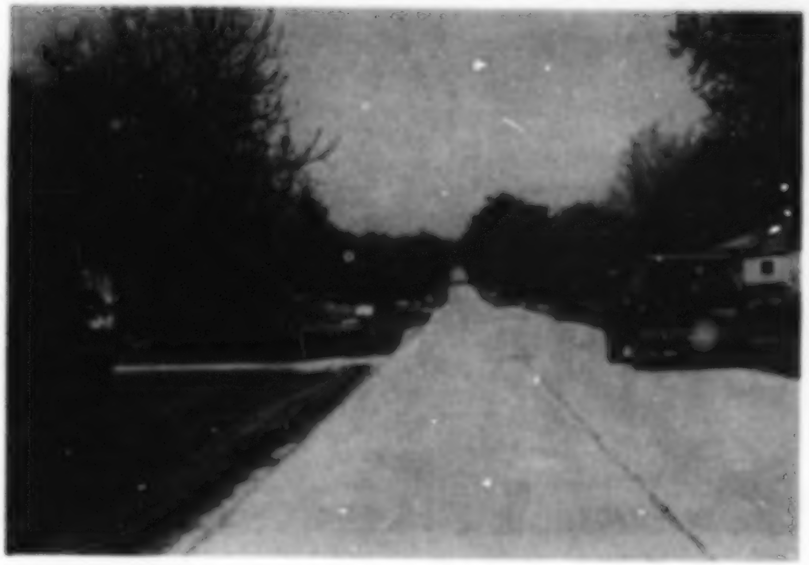

Fig. III-A-8. City of New Berlin. STORET number 413625

Stormwater, from this drainage area, is mostly conveyed via natural drainage ways to a central drainage ditch, which in some sections is undergoing bank erosion. Two small portions of the area incorporate road side culverts and open asphalt-lined drainage ways just above the monitoring station. Approximately 75% of the area is comprised of low to medium density residential housing established about 25 years ago with the upper 25% in agricultural and open lands which is slowly yielding to development. Throughout the study period construction continued on a small number of lots, however, due to the low relief in the area and the natural drainage characteristics it is believed that the construction impact on water quality was minor. Portions of the area are heavily treed, however no leaf pickup program is provided nor is leaf burning prohibited. The monitoring station is located on a drainage ditch which is tributary to the south branch of Underwood Creek, a tributary to the Menomonee River.

Fig. III-A-9. Donges Bay Road. STORET number 463001

Stormwater from this rural drainage area is conveyed via natural drainage channels to the Little Menomonee River. The land use is predominantly agricultural. The population of the City of Mequon contained in the Watershed is 780. The monitoring station is located on the Little Menomonee River approximately 3 km downstream from the headwaters.

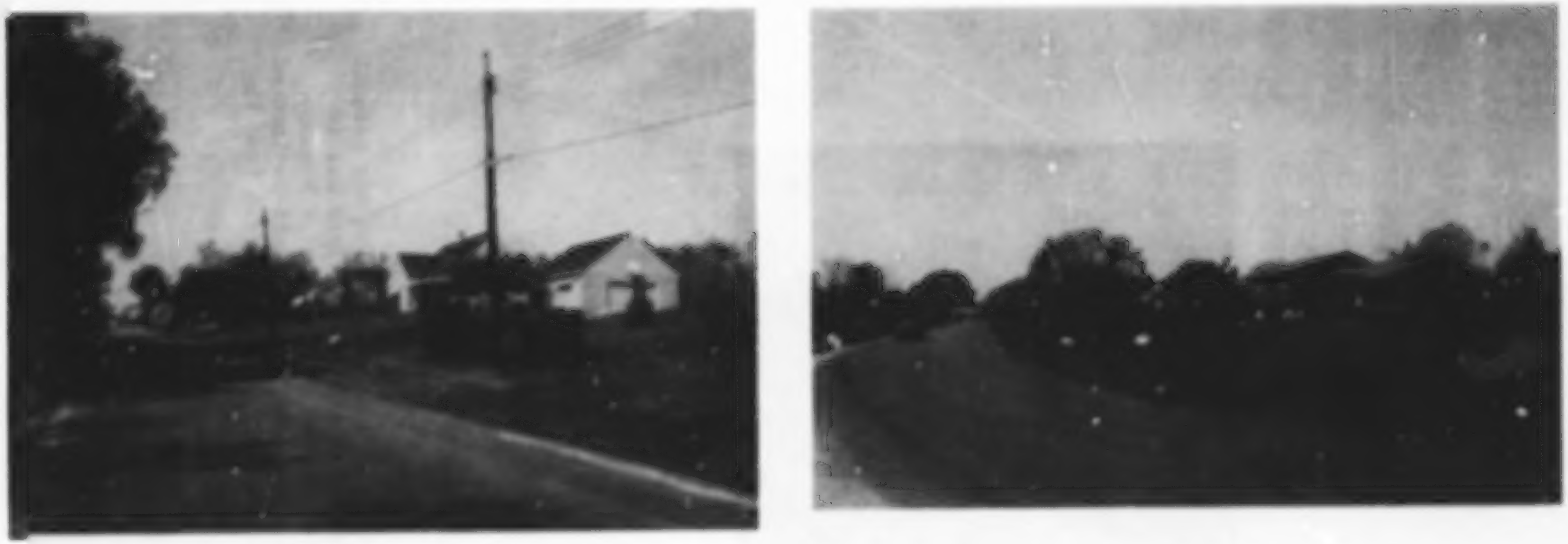

Fig. III-A-10. Village of Elm Grove. STORET number 683090

Stormwater from this drainage area is conveyed via a system of well maintained natural (grass) drainage ways to Underwood Creek. Two distinct neighborhoods exist in the drainage area separated by North Avenue. The upper half of the drainage area is an older (1950) medium density residential area which is well treed and is shown in the left photograph. The lower half of the drainage area is a newer (1965) low density residential area with large (minimum 0.2 ha) well maintained lots (right photograph). Only the largest storms (≥ 1.3 cm, total rainfall) generate runoff from this drainage area. The station is located on a drainage ditch approximately 180 m above the ditch's confluence with Underwood Creek, a major tributary of the Menomonee River.

# PART IV

# PHYSICAL CHARACTERISTICS OF THE SUBWATERSHEDS

by

G. V. SIMSIMAN
S. G. WALESH

# ABSTRACT

Important natural and cultural features of 48 subwatersheds comprising the Menomonee River Watershed are described in more detail so that variations in pollutant loadings through land surface drainage can be evaluated. Soil characteristics, land use distribution, degree of imperviousness and erosion potential in the subwatersheds are presented. Variation in erosion potential is closely associated with land use.

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## IV-1. INTRODUCTION

In analyzing land-related pollution in a watershed system it is essential to identify those land areas in the basin that are likely to serve as sources of pollutants. Source identification is particularly important in a heterogeneous basin like the Menomonee River Watershed--a basin that is diverse with respect to natural features such as soil type, land slope and vegetation and cultural features such as land use and land management practices. Watersheds that are spatially diverse with respect to the natural and man-made features are more likely to exhibit wide spatial variation with respect to potential for pollution than are more spatially homogeneous basins.

Attempts to describe in more detail the natural and man-made features of smaller units of land surface are presented herein. Some 48 subwatersheds in the Menomonee River Watershed are described so that variations in pollutant loadings through land surface drainage can be evaluated. Included in the description are soil characteristics such as textural class, slope, permeability and hydrologic group, land use and degree of imperviousness. An analysis of the spatial variation of erosion potential in the 48 subwatersheds also is presented.

## IV-2. THE SUBWATERSHEDS

The 48 subwatersheds delineated by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) are depicted in Fig. IV-1. One, or an aggregate, of subwatersheds constitutes the drainage area adjacent to a mainstem or predominantly single land use monitoring station (1).

| Subwatershed Nos. | Adjacent monitoring station nos. |
|---|---|
| 12A,B,C,D and E | 673001 |
| 10A,B,C,D and E | 683002 |
| 7A,B,C,D,E,F,G and H | 683001 |
| 11A,B and C | 463001 |
| 9 | 413011 |
| 8A,B and C | 413008 |
| 6A,B,C,D,E and F | 413007 |
| 4A,B,C and D | 413006 |
| 3A,B,C,D,E,F,G, and H | 413005 |
| 5 | 413010 |
| 2 | 413009 |
| 1A,1B and 19 | 413004 |

### Soil Characteristics

Utilizing the Land DMS, groupings were made according to soil textural class, slope, permeability and hydrologic soil class for each subwatershed. The areal distributions of the various groupings for the 48 subwatersheds are given in Tables IV-1 and IV-2.

Silt loam is the textural class that predominates in the subwatersheds (Table IV-1). Loam, silty clay loam and muck soils occupy considerably fewer areas in many of the subwatersheds and only small areas of sandy soils are found in a few of the subwatersheds. Filled areas, consisting essentially of loamy and clayey materials are found in most of the subwatersheds occupying the lower 75% of the Menomonee Watershed.

Slope is the principal natural land feature affecting soil erosion. Table IV-2 indicates that the majority of soils in the subwatersheds have slopes of 0 to 2 and 2 to 6% (nearly level to gently sloping) although substantial areas have slopes of > 6%. Erosion hazard is high in the steep areas (> 6%) but may also be high in gently sloping areas where soils are under intensive cultivation.

Permeability, defined as the rate of water movement through a saturated

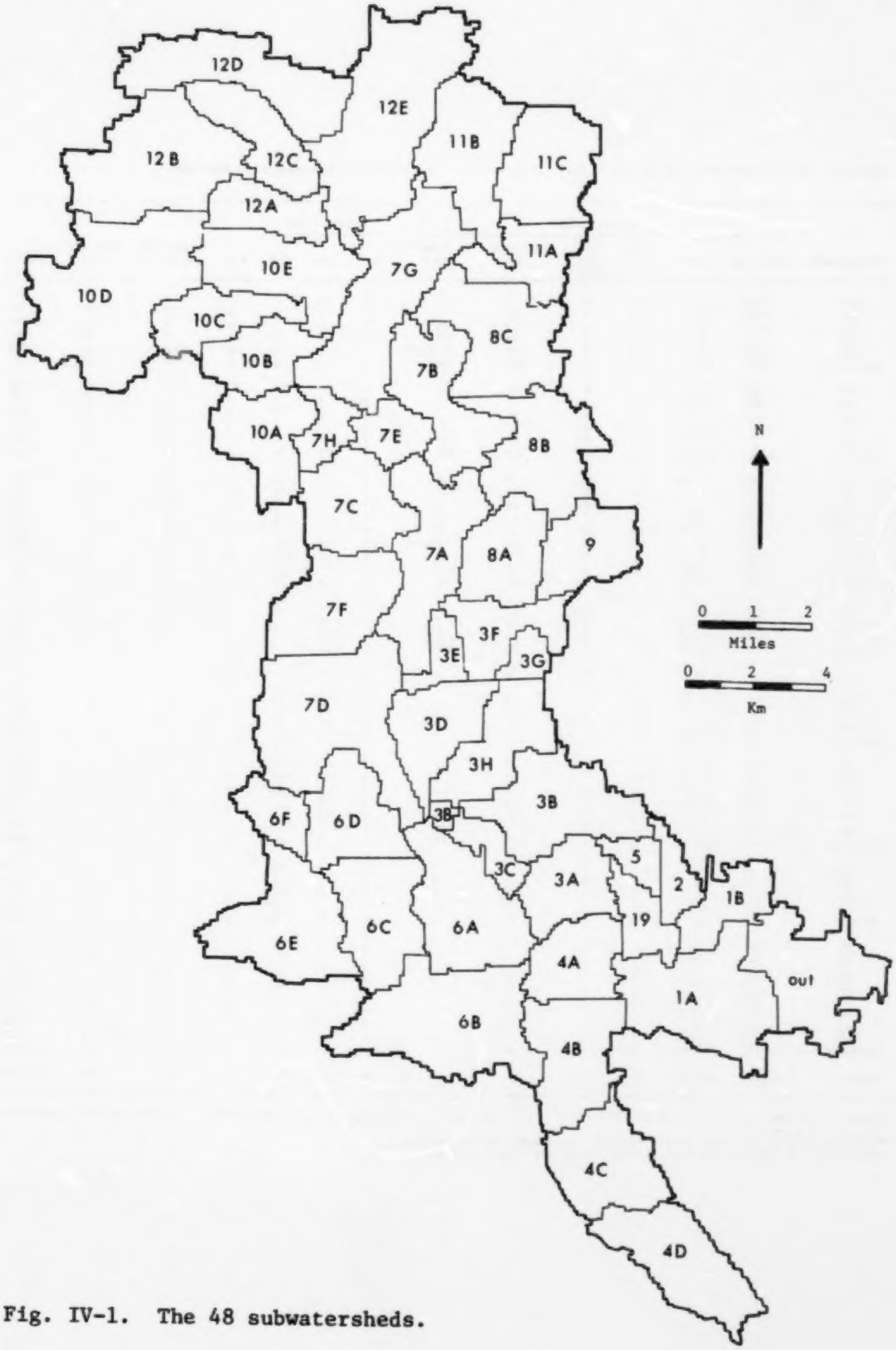
12D
12E
11B
11C
12B
12C
12A
11A
10E
7G
10D
10C
8C
10B
7B
10A
7H
7E
8B
N
7C
9
7A
8A
7F
3F
3E
3G
0 1 2
Miles
0 2 4
Km
7D
3D
3H
3B
6F
6D
3B
5
3C
3A
2
1B
19
6E
6C
6A
4A
out
1A
6B
4B
4C
4D

Fig. IV-1. The 48 subwatersheds.

Table IV-1. Areal distribution (ha) of soil textural class and other land type in the Menomonee River Watershed

| Subwatershed* | Textural class | | | | | | Filled areas | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Silt loam | Loam** | Sandy loam | Loamy pond sand | Silty clay loam | Muck/mucky peat+ | Sand | Loam | Clay | Dump | Quarry and gravel pit | Pond and lake | Total |
| 12A | 342 | 5 | 0 | 0 | 7 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 429 |
| 12B | 1,069 | 36 | 1 | 0 | 21 | 53 | 1 | 1 | 0 | 0 | 17 | 0 | 1,199 |
| 12C | 447 | 4 | 0 | 1 | 23 | 88 | 0 | 1 | 0 | 0 | 7 | 0 | 571 |
| 12D | 870 | 0 | 0 | 0 | 10 | 101 | 0 | 0 | 0 | 0 | 0 | 0 | 981 |
| 12E | 1,164 | 6 | 0 | 0 | 179 | 243(0.4) | 0 | 0 | 0 | 0 | 0 | 0 | 1,592 |
| Subtotal | 3,892 | 51 | 1 | 1 | 240 | 560 | 1 | 2 | 0 | 0 | 24 | 0 | 4,772 |
| 10A | 368 | 0 | 0 | 0 | 50 | 132 | 0 | 36 | 14 | 0 | 0 | 0 | 600 |
| 10B | 380 | 12(7) | 0 | 0 | 7 | 0 | 0 | 57 | 3 | 0 | 0 | 0 | 459 |
| 10C | 411 | 1 | 0 | 0 | 61 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 501 |
| 10D | 1,315 | 100(3) | 5 | 0 | 47 | 113 | 0 | 2 | 8 | 0 | 19 | 2 | 1,611 |
| 10E | 701 | 6 | 0 | 0 | 64 | 79 | 3 | 0 | 0 | 0 | 0 | 0 | 853 |
| Subtotal | 3,175 | 119(10) | 5 | 0 | 229 | 352 | 3 | 95 | 25 | 0 | 19 | 2 | 4,024 |
| 7A | 787 | 27(13) | 0 | 0 | 8 | 0 | 0 | 4 | 154 | 0 | 2 | 0 | 982 |
| 7B | 636 | 7 | 0 | 0 | 31 | 27 | 0 | 41 | 34 | 16 | 26 | 0 | 818 |
| 7C | 672 | 0 | 3 | 4 | 30 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 719 |
| 7D | 1,270 | 6(2) | 0 | 0 | 65 | 16 | 0 | 4 | 32 | 0 | 7 | 5 | 1,405 |
| 7E | 254 | 43(21) | 0 | 0 | 1 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 302 |
| 7F | 724 | 2 | 0 | 0 | 42 | 5(3.1) | 0 | 16 | 43 | 0 | 0 | 0 | 832 |
| 7G | 1,190 | 6 | 0 | 0 | 6 | 12 | 0 | 1 | 125 | 0 | 0 | 1 | 1,341 |
| 7H | 206 | 6(6) | 0 | 0 | 1 | 0 | 0 | 26 | 12 | 0 | 0 | 0 | 251 |
| Subtotal | 5,739 | 97(42) | 3 | 4 | 184 | 60 | 10 | 96 | 400 | 16 | 35 | 6 | 6,650 |
| 11A | 438 | 2 | 0 | 0 | 17 | 58 | 0 | 12 | 0 | 0 | 0 | 0 | 527 |
| 11B | 753 | 26(12) | 0 | 0 | 25 | 44 | 0 | 0 | 0 | 0 | 5 | 1 | 854 |
| 11C | 630 | 20(4) | 0 | 0 | 10 | 105 | 0 | 0 | 0 | 0 | 0 | 0 | 765 |
| Subtotal | 1,821 | 48(16) | 0 | 0 | 52 | 207 | 0 | 12 | 0 | 0 | 5 | 1 | 2,146 |
| 9 | 331 | 2 | 4 | 0 | 39 | 0 | 0 | 22 | 144 | 11 | 0 | 0 | 553 |
| 8A | 486 | 17(17) | 0 | 0 | 13 | 0 | 0 | 0 | 83 | 0 | 0 | 0 | 599 |
| 8B | 666 | 5 | 0 | 0 | 88 | 0.4(0.4) | 0 | 26 | 66 | 0 | 1 | 0 | 852 |
| 8C | 833 | 1 | 0 | 0 | 35 | 27 | 0 | 61 | 38 | 12 | 4 | 0 | 1,011 |
| Subtotal | 1,985 | 23(17) | 0 | 0 | 136 | 27 | 0 | 87 | 187 | 12 | 5 | 0 | 2,462 |
| 6A | 723 | 43(24) | 0 | 0 | 4 | 7 | 0 | 137 | 56 | 0 | 0 | 0 | 970 |
| 6B | 735 | 120 | 0 | 3 | 48 | 6 | 2 | 150 | 102 | 29 | 12 | 28 | 1,235 |
| 6C | 662 | 5(4) | 0 | 0 | 18 | 4 | 0 | 36 | 16 | 0 | 2 | 0 | 743 |
| 6D | 543 | 11(8) | 0 | 0 | 24 | 24 | 0 | 28 | 10 | 0 | 29 | 0 | 669 |
| 6E | 662 | 3 | 0 | 0 | 52 | 233 | 0 | 22 | 3 | 0 | 0 | 0 | 975 |
| 6F | 186 | 2 | 0 | 0 | 11 | 90 | 0 | 5 | 0 | 0 | 0 | 0 | 294 |
| Subtotal | 3,511 | 184(36) | 0 | 3 | 157 | 364 | 2 | 378 | 187 | 29 | 43 | 28 | 4,886 |
| 4A | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 | 0 | 0 | 56 |
| 4B | 53 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 54 |
| 4C | 282 | 0 | 0 | 0 | 8 | 0 | 0 | 24 | 0 | 0 | 0 | 0 | 314 |
| 4D | 357 | 0 | 0 | 0 | 55 | 17 | 0 | 9 | 20 | 0 | 0 | 0 | 458 |
| Subtotal | 720 | 0 | 0 | 0 | 64 | 17 | 0 | 33 | 48 | 0 | 0 | 0 | 862 |
| 3A | 164 | 3(2) | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 173 |
| 3B | 346 | 8(8) | 0 | 0 | 0 | 0 | 0 | 37 | 40 | 0 | 1 | 0 | 432 |
| 3C | 161 | 0 | 0 | 0 | 2 | 0 | 0 | 53 | 8 | 0 | 0 | 0 | 224 |
| 3D | 375 | 25(25) | 0 | 0 | 40 | 0 | 0 | 2 | 162 | 0 | 0 | 0 | 604 |
| 3E | 106 | 31(31) | 0 | 0 | 0 | 0 | 0 | 1 | 91 | 0 | 0 | 0 | 229 |
| 3F | 447 | 1(1) | 0 | 0 | 0 | 1 | 0 | 0 | 46 | 0 | 0 | 0 | 495 |
| 3G | 64 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 85 | 0 | 0 | 0 | 150 |
| 3H | 479 | 23(17) | 0 | 0 | 11 | 0 | 0 | 0 | 82 | 0 | 8 | 0 | 603 |
| Subtotal | 2,142 | 91(84) | 0 | 0 | 54 | 1 | 0 | 99 | 514 | 0 | 9 | 0 | 2,910 |
| Total | 23,316 | 615(205) | 13 | 8 | 1,155 | 1,588(3.9) | 16 | 824 | 1,505 | 68 | 140 | 37 | 29,285 |

*Subwatersheds 1A, 1B, 2, 5, 19 and portions of 3A, 3B, 3H, 4A, 4B, 4C, 4D and 6B with an aggregate area of 5,983 ha are highly urbanized; no soils data available.

**Alluvial soils are included in this textural class; areas are in parenthesis.

+Marshes are included in the textural class; areas are in parenthesis.

Table IV-2. Areal extent of soils grouped according to slope categories, permeability of surface soil (A horizon) and hydrologic soil group for the 48 subwatersheds in the Menomonee River Watershed

| Subwatershed* | Area, ha | Area** (ha) of soils with slope (%) of: | | | | | Area (ha) of soils with permeability (cm/hr) of: | | | | Area (ha) of soils under hydrologic soil group+++: | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0-2 | 2-6 | 6-12 | 12-20 | 20-30 | 0.5-2.0*** | 2.0-6.6+ | 6.6-12.7 | 12.7-25.4++ | B+ | C | D++ |
| 12A | 429 | 270 | 127 | 27 | 4 | 1 | 7 | 347 | 75 | 0 | 188 | 125 | 116 |
| 12B | 1,199 | 676 | 343 | 123 | 35 | 2 | 21 | 994 | 183 | 1 | 824 | 120 | 255 |
| 12C | 571 | 316 | 198 | 67 | 2 | 0 | 19 | 418 | 134 | 0 | 333 | 80 | 158 |
| 12D | 981 | 631 | 278 | 71 | 1 | 0 | 10 | 702 | 269 | 0 | 504 | 172 | 305 |
| 12E | 1,592 | 853 | 604 | 115 | 18 | 2 | 140 | 1,190 | 262 | 0 | 166 | 985 | 441 |
| Sub total | 4,772 | 2,746 | 1,550 | 403 | 60 | 5 | 197 | 3,651 | 923 | 1 | 2,015 | 1,482 | 1,275 |
| 10A | 600 | 183 | 318 | 68 | 0 | 1 | 12 | 453 | 135 | 0 | 2 | 445 | 153 |
| 10B | 459 | 71 | 289 | 33 | 5 | 0 | 6 | 449 | 4 | 0 | 50 | 392 | 17 |
| 10C | 501 | 279 | 194 | 23 | 5 | 0 | 53 | 395 | 53 | 0 | 95 | 234 | 172 |
| 10D | 1,611 | 668 | 572 | 191 | 119 | 31 | 41 | 1,369 | 200 | 1 | 892 | 380 | 339 |
| 10E | 854 | 455 | 340 | 51 | 5 | 0 | 52 | 717 | 82 | 3 | 180 | 503 | 171 |
| Sub total | 4,025 | 1,656 | 1,713 | 366 | 134 | 32 | 164 | 3,383 | 474 | 4 | 1,219 | 1,954 | 852 |
| 7A | 981 | 167 | 526 | 120 | 9 | 0 | 150 | 831 | 0 | 0 | 86 | 678 | 217 |
| 7B | 821 | 296 | 337 | 66 | 3 | 0 | 56 | 719 | 42 | 4 | 135 | 530 | 156 |
| 7C | 718 | 85 | 587 | 46 | 0 | 0 | 0 | 714 | 0 | 4 | 26 | 630 | 66 |
| 7D | 1,406 | 206 | 1,012 | 129 | 13 | 0 | 63 | 1,264 | 99 | 0 | 56 | 1,166 | 184 |
| 7E | 301 | 130 | 143 | 18 | 5 | 0 | 0 | 298 | 3 | 0 | 67 | 234 | 0 |
| 7F | 832 | 206 | 496 | 63 | 12 | 0 | 67 | 725 | 50 | 0 | 31 | 595 | 206 |
| 7G | 1,343 | 340 | 633 | 200 | 33 | 1 | 126 | 1,185 | 30 | 2 | 199 | 938 | 206 |
| 7H | 251 | 25 | 179 | 9 | 0 | 0 | 13 | 238 | 0 | 0 | 7 | 232 | 12 |
| Sub total | 6,652 | 1,457 | 3,909 | 651 | 75 | 1 | 435 | 5,974 | 233 | 10 | 505 | 5,013 | 1,056 |
| 11A | 527 | 241 | 262 | 29 | 5 | 0 | 0 | 456 | 71 | 0 | 29 | 376 | 122 |
| 11B | 852 | 364 | 372 | 97 | 13 | 0 | 0 | 815 | 37 | 0 | 173 | 576 | 103 |
| 11C | 765 | 353 | 292 | 109 | 11 | 0 | 5 | 567 | 190 | 0 | 99 | 440 | 226 |
| Sub total | 2,144 | 958 | 926 | 235 | 29 | 0 | 0 | 1,838 | 298 | 0 | 301 | 1,392 | 451 |
| 9 | 556 | 82 | 277 | 16 | 1 | 0 | 177 | 371 | 6 | 0 | 15 | 350 | 189 |
| 8A | 599 | 101 | 389 | 26 | 1 | 0 | 59 | 540 | 0 | 0 | 36 | 423 | 143 |
| 8B | 852 | 295 | 352 | 106 | 5 | 0 | 77 | 775 | 0 | 0 | 80 | 572 | 200 |
| 8C | 1,011 | 436 | 396 | 50 | 6 | 0 | 30 | 933 | 40 | 0 | 136 | 741 | 134 |
| Sub total | 2,462 | 832 | 1,137 | 181 | 12 | 0 | 165 | 2,257 | 40 | 0 | 251 | 1,736 | 376 |
| 6A | 970 | 61 | 571 | 139 | 6 | 0 | 56 | 906 | 8 | 0 | 67 | 832 | 71 |
| 6B | 1,235 | 238 | 560 | 104 | 1 | 0 | 102 | 1,034 | 94 | 5 | 166 | 798 | 270 |
| 6C | 763 | 107 | 303 | 190 | 10 | 0 | 15 | 744 | 4 | 0 | 74 | 589 | 100 |
| 6D | 660 | 168 | 331 | 110 | 13 | 0 | 10 | 605 | 56 | 0 | 71 | 469 | 120 |
| 6E | 975 | 358 | 506 | 65 | 15 | 5 | 5 | 689 | 280 | 1 | 111 | 543 | 321 |
| 6F | 293 | 118 | 137 | 30 | 4 | 0 | 0 | 197 | 97 | 0 | 43 | 138 | 113 |
| Sub total | 4,885 | 1,030 | 2,406 | 638 | 49 | 5 | 188 | 4,165 | 526 | 6 | 532 | 3,369 | 1,004 |
| 4A | 56 | 0 | 27 | 1 | 0 | 0 | 28 | 28 | 0 | 0 | 0 | 28 | 28 |
| 4B | 54 | 1 | 53 | 0 | 0 | 0 | 0 | 54 | 0 | 0 | 0 | 54 | 0 |
| 4C | 314 | 0 | 282 | 0 | 0 | 0 | 0 | 314 | 0 | 0 | 0 | 314 | 0 |
| 4D | 458 | 70 | 364 | 14 | 1 | 0 | 25 | 418 | 20 | 0 | 0 | 396 | 61 |
| Sub total | 882 | 71 | 726 | 15 | 1 | 0 | 53 | 814 | 20 | 0 | 0 | 792 | 89 |
| 3A | 173 | 22 | 93 | 47 | 5 | 0 | 0 | 173 | 0 | 0 | 34 | 139 | 0 |
| 3B | 432 | 11 | 335 | 6 | 2 | 0 | 40 | 392 | 0 | 0 | 24 | 366 | 42 |
| 3C | 224 | 13 | 126 | 23 | 0 | 0 | 8 | 216 | 0 | 0 | 30 | 174 | 10 |
| 3D | 604 | 67 | 365 | 4 | 5 | 0 | 160 | 444 | 0 | 0 | 12 | 412 | 180 |
| 3E | 229 | 32 | 87 | 10 | 0 | 0 | 70 | 151 | 0 | 0 | 33 | 104 | 92 |
| 3F | 495 | 36 | 384 | 22 | 7 | 0 | 46 | 448 | 1 | 0 | 4 | 410 | 80 |
| 3G | 151 | 1 | 65 | 0 | 0 | 0 | 85 | 66 | 0 | 0 | 0 | 68 | 83 |
| 3H | 602 | 26 | 476 | 10 | 0 | 0 | 82 | 520 | 0 | 0 | 27 | 488 | 88 |
| Sub total | 2,910 | 208 | 1,931 | 130 | 19 | 0 | 479 | 2,430 | 1 | 0 | 192 | 2,161 | 555 |
| Total | 29,286 | 9,048 | 14,625 | 2,605 | 300 | 43 | 1,853 | 26,883 | 2,529 | 21 | 5,080 | 19,352 | 5,043 |

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*Subwatersheds 1A, 1B, 2, 5, 19 and portions of 3A, 3B, 4B, 4C, 6D and 6B with an aggregate area of 5,983 ha are highly urbanized; no soils data available.

**Does not include areas of filled lands, dump, gravel pit lakes, etc. where no slope was assigned; aggregate area of these land categories is 2,505 ha.

***Includes areas of made land filled with clay materials.

+Includes areas of made land filled with loamy materials.

++Includes areas of made land filled with sand and gravel.

+++Hydrologic soil group A is present but area is negligible.

+Includes areas of made land filled with sand and loamy materials.

++Includes areas of made land filled with clay materials.

soil, determines to a large extent the amount of water available for overland flow during storm events. Generally, fine-textured soils exhibit lower permeability than coarse-textured soils. Most of the soils in the subwatersheds have low permeability (2.0 to 6.4 cm/hr) in their A horizons. Soils with very low permeability (0.5 to 2.0 cm/hr) and moderate to high permeability (> 6.4 cm/hr) are not widespread.

Soils in the subwatersheds were classified into hydrologic groups as defined earlier (Part III). Group C soils are dominant in most of the subwatersheds followed in order of importance by Group D soils (Table IV-2). Soils in these groups have high runoff potential because of low infiltration rate, low permeability and poor internal drainage.

## Land Use

The Menomonee River Watershed features a variety of land uses. Aggregation into 14 land use categories by subwatersheds were made for the 1975 SEWRPC land use inventory (Table IV-3). Land development occurs in almost all of the subwatersheds although the degree of development is more pronounced in several upper subwatersheds. Row croplands are found mostly in the upper subwatersheds. Generally, the lower subwatersheds are highly urbanized while the upper ones are essentially rural. Greater changes in land use would be expected in the upper subwatersheds due to urbanization brought about by increasing population pressure.

The kinds and amounts of land-derived pollutants depend on the land use as affected by man's activities, degree of imperviousness, soil texture, degree of erodibility and slope. While slope and soil texture are the predominant factors in rural subwatersheds, the main factor governing inputs from urban and urbanizing subwatersheds is likely to be degree of imperviousness of the land surface. The degree of imperviousness associated with the subwatersheds ranges from 2 to 70% (Table IV-3). More impervious areas are located in the lower subwatersheds which is indicative of the variation in extent of urban development in the Watershed as a whole.

## Soil Erosion Potential

An analysis was made by SEWRPC (2) to identify the spatial variation of erosion potential in the Menomonee River Watershed using the Universal Soil Loss Equation (USLE) as the basic analytical tool. The USLE (3) predicts primarily long-term average annual soil erosion potential from a parcel of land having a given combination of the various natural and man-made features and is limited to the erosion caused by rainfall in rill and inter-rill areas. It does not necessarily predict the amount of soil and other particulate matter moving from the land surface to the receiving waters. The USLE was applied within the context of the Land DMS.

The USLE and definition of the various terms within the equation are

Table IV-3. Land use categories (1975) in the 48 subwatersheds of the Menomonee River Watershed

| No. | Area, ha | Land use* distribution, % | | | | | | | | | | | | | | Imperviousness, % | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total | Connected |
| 12A | 429 | 0.4 | 3.3 | 0 | 6.7 | 0.7 | 0.7 | 7.8 | 17 | 48 | 2.6 | 0.4 | 0 | 0 | 4.0 | 17 | 6 |
| 12B | 1,200 | 4.3 | 3.2 | 1.9 | 0.3 | 6.2 | 1.6 | 3.6 | 36 | 29 | 6.0 | 7.0 | 0.5 | 0 | 0.2 | 7 | 1 |
| 12C | 571 | 0.6 | 1.8 | 0 | 0 | 9.6 | 4.9 | 1.6 | 31 | 30 | 9.4 | 4.8 | 0.5 | 0 | 0.4 | 8 | 1 |
| 12D | 981 | 0 | 2.4 | 0 | 0 | 3.5 | 1.5 | 0.3 | 45 | 32 | 12 | 3.2 | 0.5 | 0 | 0 | 2 | 1 |
| 12E | 1,592 | 0 | 0.7 | 0 | 0 | 4.3 | 7.4 | 0.4 | 31 | 30 | 24 | 8.6 | 0.2 | 0 | 0 | 2 | 1 |
| 10A | 599 | 0.2 | 4.0 | 0 | 2.0 | 37 | 0.2 | 4.4 | 1.3 | 25 | 1.3 | 24 | 0 | 0.2 | 0.6 | 23 | 12 |
| 10B | 459 | 1.1 | 4.6 | 5.9 | 1.8 | 36 | 2.5 | 1.9 | 15 | 25 | 4.5 | 0.3 | 0 | 0 | 1.0 | 20 | 2 |
| 10C | 502 | 0.1 | 3.1 | 2.7 | 0 | 9.6 | 1.4 | 1.8 | 31 | 32 | 13 | 5.3 | 0 | 0 | 0 | 7 | 1 |
| 10D | 1,610 | 1.8 | 1.1 | 2.2 | 0.1 | 12 | 1.4 | 5.9 | 19 | 39 | 13 | 4.4 | 0.2 | 0 | 0.5 | 8 | 2 |
| 10E | 853 | 0 | 0.2 | 0.8 | 0 | 14 | 1.2 | 1.7 | 37 | 26 | 8.5 | 11 | 0 | 0 | 0.1 | 6 | 2 |
| 7A | 981 | 3.1 | 5.7 | 8.0 | 0 | 18 | 0.6 | 5.0 | 0.9 | 40 | 7.0 | 2.2 | 0 | 0 | 1.7 | 23 | 11 |
| 7B | 830 | 5.9 | 5.9 | 2.7 | 0.4 | 4.8 | 1.3 | 1.5 | 18 | 51 | 2.0 | 0.8 | 0 | 2.6 | 0.6 | 11 | 1 |
| 7C | 718 | 0 | 3.1 | 0 | 0.2 | 48 | 0.7 | 0.7 | 9.0 | 28 | 2.6 | 0.7 | 0 | 0 | 0 | 17 | 1 |
| 7D | 1,406 | 1.1 | 3.2 | 0 | 0.1 | 56 | 0.4 | 0.5 | 5.1 | 19 | 3.6 | 5.0 | 0 | 0 | 0.3 | 18 | 1 |
| 7E | 301 | 2.7 | 8.2 | 3.5 | 0 | 28 | 1.0 | 3.0 | 5.5 | 41 | 5.9 | 0 | 0 | 0 | 0.8 | 24 | 7 |
| 7F | 832 | 1.1 | 6.6 | 0 | 0 | 24 | 0.9 | 4.9 | 21 | 37 | 3.9 | 0.4 | 0 | 0 | 0.2 | 12 | 1 |
| 7G | 1,343 | 2.7 | 4.9 | 2.4 | 0.2 | 8.3 | 1.5 | 0.5 | 28 | 32 | 8.9 | 4.1 | 0.2 | 0 | 0.1 | 11 | 1 |
| 7H | 251 | 0.2 | 8.3 | 0 | 4.5 | 65 | 0 | 4.6 | 0.1 | 14 | 0.4 | 1.3 | 0.1 | 0 | 0 | 34 | 17 |
| 11A | 327 | 0 | 1.2 | 0 | 0 | 2.4 | 2.5 | 0.2 | 68 | 18 | 6.2 | 1.5 | 0 | 0 | 0.2 | 5 | 1 |
| 11B | 852 | 0 | 0.2 | 0 | 0.2 | 7.6 | 1.4 | 2.7 | 33 | 38 | 10 | 9.0 | 0.0 | 0 | 1.5 | 5 | 2 |
| 11C | 765 | 0 | 1.3 | 0 | 0 | 12 | 1.5 | 2.1 | 39 | 31 | 12 | 0.0 | 0.7 | 0 | 0 | 3 | 1 |
| 9 | 555 | 3.4 | 15 | 1.6 | 6.8 | 41 | 0.2 | 3.9 | 0.2 | 26 | 0.6 | 0.1 | 0 | 2.6 | 0.4 | 42 | 27 |
| 8A | 590 | 0.1 | 2.0 | 7.7 | 2.9 | 36 | 0.6 | 4.5 | 2.6 | 40 | 3.1 | 0.6 | 0 | 0 | 0.5 | 26 | 10 |
| 8B | 853 | 1.3 | 7.8 | 0 | 2.9 | 13 | 0.9 | 5.8 | 14 | 45 | 5.5 | 2.9 | 0 | 1.6 | 0 | 13 | 8 |
| 8C | 1,011 | 2.2 | 9.8 | 0 | 1.9 | 4.3 | 1.0 | 6.2 | 26 | 28 | 13 | 6.9 | 0 | 0 | 0.4 | 12 | 1 |
| 6A | 970 | 2.0 | 8.9 | 6.1 | 2.9 | 67 | 0 | 1.0 | 0 | 30 | 0.4 | 0 | 0 | 3.8 | 0.1 | 41 | 17 |
| 6B | 1,323 | 4.5 | 15 | 5.7 | 2.6 | 41 | 0 | 2.8 | 0 | 26 | 0.8 | 1.0 | 0 | 0.3 | 0.0 | 30 | 12 |
| 6C | 744 | 0.5 | 6.9 | 0 | 1.8 | 58 | 0.1 | 4.7 | 0 | 20 | 6.3 | 1.0 | 0 | 0 | 0.1 | 23 | 1 |
| 6D | 688 | 5.1 | 1.0 | 0 | 1.3 | 33 | 0.4 | 4.9 | 0 | 24 | 4.4 | 0.3 | 0 | 0 | 0.1 | 14 | [illegible] |
| 6E | 974 | 0 | 8.3 | 0 | 0 | 65 | 0.3 | 5.8 | 3.0 | 28 | 7.4 | 4.5 | 0 | 0 | 0.2 | 21 | 1 |
| 6F | 294 | 0.3 | 4.3 | 0 | 0 | 25 | 0.3 | 0.1 | 0 | 50 | 10 | 10 | 0 | 0 | 0 | 10 | 1 |
| 4A | 565 | 4.0 | 11 | 7.0 | 5.6 | 67 | 0 | 0.2 | 0 | 26 | 0 | 0 | 0 | 0 | 0 | 51 | 33 |
| 4B | 752 | 2.5 | 9.1 | 0.4 | 2.3 | 60 | 0 | 0.4 | 0 | 18 | 0 | 0 | 0 | 0 | 0.3 | 48 | 30 |
| 4C | 707 | 0.1 | 5.5 | 0 | 11 | 67 | 0 | 2.5 | 0 | 13 | 0 | 0 | 0 | 0 | 0.1 | 52 | 32 |
| 4D | 790 | 0 | 6.4 | 2.7 | 5.1 | 60 | 0.1 | 5.2 | 1.9 | 25 | 1.7 | 1.1 | 0 | 1.6 | 0.1 | 32 | 20 |
| 3A | 527 | 0.2 | 5.8 | 0 | 4.1 | 42 | 0 | 0.1 | 1.5 | 43 | 2.1 | 0 | 0 | 0 | 1.7 | 46 | 32 |
| 3B | 940 | 1.3 | 4.5 | 0.2 | 5.0 | 69 | 0 | 0.5 | 0 | 19 | 0 | 0 | 0 | 0 | 0.7 | 51 | 30 |
| 3C | 225 | 0 | 20 | 4.7 | 8.4 | 23 | 0 | 0.8 | 0 | 39 | 2.5 | 0 | 0 | 0 | 1.0 | 47 | 33 |
| 3D | 605 | 15 | 24 | 2.1 | 0.5 | 28 | 0 | 1.4 | 0 | 30 | 1.1 | 0 | 0 | 0.1 | 0.6 | 58 | 18 |
| 3E | 230 | 7.9 | 36 | 7.9 | 3.7 | 11 | 0 | 0.6 | 0 | 33 | 0.5 | 0 | 0 | 0.6 | 1.3 | 48 | 36 |
| 3F | 486 | 3.0 | 17 | 1.9 | 9.1 | 32 | 0.1 | 2.4 | 0.6 | 33 | 0 | 0 | 0 | 0 | 0.6 | 46 | 30 |
| 3G | 151 | 0.2 | 85 | 0 | 4.4 | 8.6 | 0 | 0 | 0 | 1.5 | 0 | 0 | 0 | 0 | 0 | 23 | 17 |
| 3H | 862 | 0.1 | 15 | 1.2 | 4.4 | 32 | 0 | 1.8 | 0 | 37 | 0 | 0 | 0 | 0 | 0.7 | 47 | 30 |
| 5 | 175 | 0 | 5.6 | 0 | 0.4 | 87 | 0 | 2.0 | 0 | 5.3 | 0 | 0 | 0 | 0 | 0 | 55 | 33 |
| 2 | 182 | 0 | 7.2 | 0 | 3.3 | 77 | 0 | 0.2 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 58 | 36 |
| 1A | 1,163 | 17 | 25 | 3.8 | 2.3 | 33 | 0.1 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0.0 | 75 | 57 |
| 1B | 389 | 0.3 | 18 | 5.9 | 5.5 | 40 | 0 | 0.2 | 0 | 18 | 0 | 0 | 0 | 3.2 | 0.0 | 90 | 61 |
| 1C | 305 | 5.0 | 12 | 0 | 2.5 | 65 | 0 | 1.1 | 0 | 13 | 0 | 0 | 0 | 0.4 | 0.0 | 56 | 36 |
| Total | 34,307 | 2.6 | 7.3 | 1.8 | 1.9 | 29 | 0.7 | 3.1 | 14 | 29 | 5.7 | 3.1 | 0.1 | 0.3 | 0.4 | 24 | 13 |

*Land use categories are: 1-industrial, 2-commercial, 3-freeway (other roads are proportionately distributed among the other land uses), 4-high density residential, 5-medium density residential, 6-low density residential, 7-land under development, 8-row crops, 9-pasture and small grains, 10-forested land and woodlots, 11-wetlands, 12-feedlots, 13-landfill and dumps, 14-water areas (land use categories are described in Table III-5 found in (7).

as follows:

$$E = A \times R \times K \times LS \times C \times P$$

where:

E = soil loss by water erosion in rill and inter-rill areas (Tonnes/ha/yr).

A = area (ha).

R = a rainfall factor that accounts for the erosive forces of rainfall and runoff [EI (erodibility index) units/yr].

K = soil erodibility factor that reflects the physical and chemical properties of a particular soil (Tonnes/ha/EI unit).

LS = slope-length factor that reflects the effects of length and steepness of the land surface (dimensionless).

C = a cropping-management factor that reflects the influence of vegetation, mulch and the soil surface (dimensionless).

P = erosion control practice factor that is similar to the cropping-management factor but accounts for practices superimposed on the land surface such as contouring, terracing, compacting, sediment basins, and control structures (dimensionless).

Analysis of erosion potential by subwatersheds indicates high variability of erosion rate in the Watershed as a whole (Table IV-4). Based on area, most of the soils in the subwatersheds have low erosion potential (< 4.5 Tonnes/ha/yr). However, considerable soil areas have high erosion potential (> 4.5 Tonnes/ha/yr) particularly in the upper subwatersheds. The unit erosion potential ranges from 0.41 to 9.13 Tonnes/ha/yr; a variation of over 20 times for the 48 subwatersheds.

An examination of the terms of the USLE reveals that the unit erosion potential is determined largely by the soil erodibility factor (K), the slope-length factor (LS) and the cropping-management factor (C). The area-weighted values of these parameters are given in Table IV-4. Area weighted values for the K factor for the 48 subwatersheds range from 0.19 to 0.48 (maximum to minimum ratio is 2.5), the LS factor values range from 0.326 to 0.885 (ratio 2.7) and C factor from 0.011 to 0.145 (ratio 13). Considering the range in values of these factors it is likely that the cropping-management factor is the primary determinant of variations in unit potential erosion, followed in order of importance by the erodibility and slope-length factors.

The cropping-management factor is closely related to land uses (2). The highest cropping-management factors are associated with land uses such as agriculture (0.08), land fills and dumps (1.00), extractive areas (1.00), and land under development (1.00). All other land uses have cropping

management factors of 0.01 or less. It is apparent that land uses associated with high C values have high erosion potential.

Subwatersheds 11B, 8A, 6D, 10D, 7D and 8B have the highest unit erosion potential. The high erosion rates in these subwatersheds are generally associated with agriculture and/or land under development (Table IV-3).

## REFERENCES - IV

1. Simsiman, G. V., J. Goodrich-Mahoney, G. Chesters and R. Bannerman. Land Use, Population and Physical Characteristics of the Menomonee River Watershed. Part III: Description of the Watershed. Final Report of the Menomonee River Pilot Watershed Study, Vol. 2, U.S. Environmental Protection Agency, 1979.

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3. Wischmeier, W. H. Use and Misuse of the Universal Soil Loss Equation. J. Soil Water Conserv. 31 (1):5-9, 1976.